PB80-202229

Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds Volume II: Emission Inventory Requirements for Photochemical Air Quality Simulation Models

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Sep 79

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/4-79-018
September 1979

Air

PB80-202229

EPA

Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds

Volume II: Emission Inventory Requirements for Photochemical Air Quality Simulation Models

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.
450/4-79-018

2.

3. RECIPIENT'S ACCESSION NO.
PB 80 202229

4. TITLE AND SUBTITLE
Procedures for the Preparation of Emission Inventories For Volatile Organic Compounds, Volume II: Emission Inventory Requirements for Photochemical Air Quality Simulation Models

5. REPORT DATE
September 1979

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards,
Monitoring and Data Analysis Division (MD-14)
Research Triangle Park, NC 27711

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS

13. TYPE OF REPORT AND PERIOD COVERED

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES
Project Officer - Thomas F. Lahre

16. ABSTRACT

This is a companion document to Volume I, which describes procedures for compiling the annual countywide inventory of volatile organic compound (VOC) emissions. Volume II describes procedures for converting the annual countywide emission inventory to the detailed inventory needed for photochemical models. The detailed inventory contains hourly gridded emissions (by species class for VOC and NO_x) for a typical weekday during the oxidant season.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Apportioning	Spatial Resolution		
Emissions Inventory	Temporal Resolution		
Gridding	Species Resolution		
Hydrocarbons	Species		
Nitrogen Oxides	Volatile Organics		
Photochemical Models			
Projections			

18. DISTRIBUTION STATEMENT

19. SECURITY CLASS *(This Report)*

20. SECURITY CLASS *(This page)*

21. NO. OF PAGES

22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA-450/4-79-018

Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds

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EPA Project Officer: Thomas F. Lahre

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

September 1979

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This document has been reviewed by the Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, and approved for publication. Subject to clarification, the contents reflect current Agency thinking.

Publication No. EPA-450/4-79-018

ACKNOWLEDGMENTS

This document was prepared by Tom Lahre of the Monitoring and Data Analysis Division, OAQPS, EPA in conjunction with personnel from Pacific Environmental Services (PES) and PEDCo Environmental. Dr. Lowell Wayne of PES was primarly responsible for much of the material in Chapters 6, 7, and the appendices, and provided invaluable review comments on the rest of the document. Mr. Keith Rosbury of PEDCo assembled much of the material in Chapter 5.

The authors wish to thank the numerous persons involved in the planning and review of this document as well as those groups that pioneered many of the inventory concepts developed herein.

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1.0 INTRODUCTION

1.1 PURPOSE

This document is a companion volume to Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds, Volume I.[1] Volume I describes procedures for compiling annual inventories of volatile organic compound (VOC) emissions for relatively large areas, such as counties. The less detailed emission inventory that results from the procedures in Volume I is primarily intended to be used as input to simple source/receptor relationships, such as the Empirical Kinetic Modeling Approach (EKMA)[2].

Volume II describes procedures for compiling VOC emission inventories in sufficient detail for use in photochemical air quality simulation models. Because photochemical models can simulate the hour-by-hour photochemistry occurring over numerous, small subcounty areas (i.e., grid cells), more temporal and spatial resolution of input data must be included in the inventories that provide emission data to these models. Total VOC (and NO_x) emissions must be apportioned into species classes, and information may be required on other pollutants such as carbon monoxide, sulfur dioxide, and particulates. Further, in applying photochemical air quality simulation models to the evaluation of proposed control strategies, it is necessary to provide "projection inventories," i.e., anticipated emission inventories for future years, at the same level of detail as required for current inventories. Methodologies for providing this added detail are presented in this document. In each case, the requirements for projection inventories are equivalent to those for current or "base year" inventories.

The basic emission inventory requirements are in many respects quite similar for photochemical models and the less data-intensive source/receptor relationships. For both, much of the same information is obtained from the same sources. Moreover, the resulting inventories are used by air pollution control agencies for the same general purpose, i.e., for developing control strategies that will assure the achievement and maintenance of the National Ambient Air Quality Standard for ozone.[3] Hence, there are many activities (e.g., data collection, emission calculations) to which the same considerations and techniques apply, regardless of whether the inventory is being developed for a photochemical model or a simple source/receptor relationship. In general, where procedures are similar to those already described in detail in Volume I, they are not repeated here. Thus, it is important that the reader be familiar with the content of Volume I to thoroughly understand the procedures described in this document.

Several different photochemical simulation models exist or are being developed whose specific emission inventory input requirements differ in some respects. Volume II does not describe the exact detailed specifications and formats of the emission inventories needed as input to each model. This would be extremely difficult and tedious because many versions of these models are currently evolving. Nor is it the intent of Volume II to set forth criteria to help the user select an appropriate photochemical model. Instead, this document summarizes the steps that must be carried out to provide inventories that are generally suitable for use in any photochemical model. To complement this general discussion, a brief description of the emission requirements of currently available photochemical models is presented in Appendix A. In each case, the requirements for projection inventories are equivalent to those for current or "base year" inventories.

It is assumed at the outset that an annual, countywide emission inventory is available as a starting point for the photochemical modeling effort. This basic type of inventory is useful both in planning the more detailed emission inventory effort and as a source of certain data. For most urban areas, some sort of basic emission inventory has already been performed.

1.2 BACKGROUND

As described in Volume I, the emission inventory is an essential element in an ozone control program. It tells the agency what sources are present in an area and how much of each ozone precursor pollutant is emitted by each source. The emission inventory is ultimately utilized in conjunction with a source/receptor relationship of some kind for the development of an ozone control strategy.

Two basic approaches may be used in a control program for relating photochemical oxidant (expressed as ozone) to VOC and NO_x. The first involves the use of empirical relationships such as EKMA or rollback to relate ambient ozone with precursor emissions over fairly broad geographical areas. These simple models provide answers to questions such as "what level of overall volatile organic compound emission control is needed to attain the ozone standard in an urban area?" or "what reduction in maximum ozone concentration will accompany a specified reduction in ambient levels of volatile organic compounds?" For these simple source/receptor relationships, it is generally sufficient to use annual or seasonally adjusted estimates of total reactive VOC emissions for the entire area of concern. This type of emission estimate can be obtained using the procedures outlined in Volume I.

The second basic approach for relating ozone to precursors involves the use of photochemical air quality simulation models.

These models offer a more theoretically sound approach for control strategy development in that they attempt to simulate the photochemical reactions that occur over an urban region during each hour of a typical day for which a model is being applied. Because of their ability to provide detailed spatial and temporal information on both ozone levels and precursor pollutants and because they can directly relate emissions to ozone concentrations, photochemical simulation models offer considerable potential for use in control strategy design and evaluation.

In addition to answering the limited questions that the simpler empirical source/receptor relationships may address, photochemical models enable strategists to make more sophisticated determinations relating to control program development. For example, photochemical models enable control agencies to judge whether it is more effective to control only certain precursor sources within an urban area rather than all sources, or where (and when) benefits from various control options are most likely to occur within an urban area. Another application is the development of environmental impact assessments, since photochemical models allow an agency to evaluate the impact of new precursor sources (e.g., a major highway) at various receptor locations. Photochemical models are also useful in basic scientific research, such as in validation studies of atmospheric photochemistry and dispersion mechanisms.

There are two major types of photochemical models: trajectory and grid. Trajectory models (also known as Lagrangian models) estimate the concentration of ozone and other chemical species within a specified parcel of air. These models "follow" a specific hypothetical air parcel and estimate pollutant concentrations within the selected parcel during subsequent hours. The concentrations that are estimated result from an interaction of chemical reactions among precursor pollutants within the parcel and emissions encountered along the parcel's trajectory. Meteorological variables also play key roles in determining concentrations of ozone and other pollutants in the selected parcel. The trajectory of the parcel (and hence the emissions encountered), the vertical and horizontal exchange with surrounding air, and some key chemical reaction rates are all determined by prevailing meteorological conditions.

Grid models (also called Eulerian models) calculate pollutant concentrations at fixed locations in space at specified times. The concentrations estimated at each location result from interaction among emissions, chemical reactions, and transport and dilution introduced by prevailing meteorological conditions. Pollutant concentrations are calculated for each cubicle of a three-dimensional framework in the entire region of interest. A cubicle might have horizontal dimensions of 1 to 10 kilometers on a side and be 50 to 500 meters deep. Some Eulerian and Lagrangian models are designed to provide vertical (as well as horizontal) resolution of pollutant concentrations by using a vertical "stack" of cubicles.

In order for photochemical simulation models to produce the temporal and spatial resolution of which they are capable, the inventories that supply emissions data to these models must be considerably more detailed than inventories based on the procedures prescribed in Volume I. Basically, the emission inventory used in a photochemical modeling application must provide more detail in three ways. First, instead of providing a single emission estimate for each precursor pollutant for the entire area of concern (e.g., one county), emission estimates must be provided for each individual cell of a grid system within the area. Second, instead of annual or seasonally adjusted emissions, typical hour-by-hour emission estimates must be provided. Third, instead of total reactive VOC, specific information must be provided on quantities of several classes of VOC. Emission information for NO and NO_2 is also required. In addition, some models require spatially and temporally resolved emission estimates of CO, SO_2, and particulates and, if the model provides for vertical resolution of pollutants, knowledge of stack and exhaust gas parameters for each large point source may be necessary.

The basic emission inventory requirements for trajectory photochemical models are similar to those for their grid model counterparts. The main difference is that for a single trajectory, emissions are needed only along the trajectory. However, if a large number of trajectories must be run to study control strategies over an entire region, the emission inventory requirements for a trajectory model become essentially identical to those for a grid model.

1.3 CONTENTS OF VOLUME II

This document offers technical assistance to those engaged in planning and development of detailed emission inventories for use in photochemical air quality simulation models.

Chapter 1 discusses the purpose of Volume II and its relationship to Volume I; it also includes an introductory description of the two types of photochemical air quality simulation models and their emission inventory requirements. Chapter 2 describes various technical considerations that aid in the planning and design of the detailed emission inventory, and presents a brief overview of the entire emission inventory process. Chapter 2 is intended to provide an overall perspective of the detailed inventory requirements for those who will actually be utilizing the remainder of the document, while at the same time serving as an executive summary to those concerned only at a general level with the inventory process. Chapters 3 through 8 provide detailed "how to" procedures for supplying the detail that is necessary to compile an inventory for use in a photochemical model.

In addition, Appendix A briefly describes emission input requirements for available versions of photochemical models, while Appendix B contains a glossary of technical terms used in this document.

References for Chapter 1.0

1. Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds, Volume I, EPA-450/2-77-028, U.S. Environmental Protection Agency (OAWM, OAQPS, MDAD), Research Triangle Park, NC, December 1977.

2. Uses, Limitations and Technical Basis of Procedures for Quantifying Relationships Between Photochemical Oxidants and Precursors, EPA-450/2-77-021a, U.S. Environmental Protection Agency (OAWM, OAQPS, MDAD), Research Triangle Park, NC, November 1977.

3. 40 CFR 50.9, "National Primary and Secondary Ambient Air Quality Standards for Ozone", 1978.

2.0 INVENTORY PLANNING AND DESIGN CONSIDERATIONS

The same basic steps (viz., planning; data collection, handling, and analysis) are necessary to compile both a detailed emission inventory for photochemical modeling and a less detailed inventory for EKMA or rollback. Because the same basic steps are involved, many of the planning and design considerations discussed in Chapter 2 of Volume I are generally applicable. However, since the requirements of photochemical modeling inventories are more rigorous than those of the simpler source/receptor relationships, a number of additional planning considerations must be taken into account. The primary purpose of this chapter is to highlight the additional inventory requirements of photochemical models and to discuss the added responsibilities imposed on the agency developing an emission inventory for use in a photochemical modeling effort.

2.1 DETERMINATION OF THE GRID SYSTEM

A primary planning consideration is the selection of a grid system compatible with the proposed modeling system. The grid system is defined by two main elements: (1) the grid boundary, outlining the area to be modeled, and (2) the collection of subareas (called "cells") within which emissions are to be determined for use in the model. For most models, the grid boundary must be rectangular and the cells must be squares, all of equal size. (The "grid spacing" is the length of the side of one square grid cell.)

Thus, at the outset of the inventory effort, the agency must define both the overall size and shape of the grid to be modeled and the size and number of grid cells that compose the grid. It is extremely important to develop an appropriate grid system at the start so that emission estimates for various types of sources, including area sources, are referenced to a single grid system. A great deal of wasted effort results if a common grid system is not adopted or if the grid system is redefined during the course of the compilation effort. In addition, since a number of factors not related to the inventory (e.g., meteorology) must be taken into account when defining the system, those responsible for the inventory should consult the appropriate modeling specialists, planners, and meteorologists before collecting data, to ensure that the grid system meets the general objectives of the photochemical modeling program.

The area covered by the inventory grid should be as large as practical, for several reasons. It is generally desirable to include all major precursor emission sources within the grid. In cases where the exact area to be modeled is not certain, a large emission grid ensures that a smaller area chosen within the emission grid can be modeled adequately. In this sense, the emission grid can be larger than the actual grid used for modeling.

The grid should be large enough to encompass as many ozone and precursor pollutant monitoring stations as possible, since an important step in the application of the photochemical dispersion model involves "validating" the model, i.e., determining whether the observed ozone and precursor pollutant concentrations at each monitoring station agree with values predicted by the model. Ambient air measurements are also necessary to define boundary pollutant concentrations in the validation process.

The grid should also be large enough to encompass areas of current limited land use activity that are expected to develop as a result of projected growth. Since an important application of photochemical models is to evaluate ozone concentrations in future years, land use projections should be consulted to determine what types of growth are expected and in what areas.

Finally, the grid should be large enough to encompass the effects of meteorology in the model area. Since peak oxidant levels often occur downwind of the urban center, it is desirable to include as much "downwind area" as possible in the grid so that the model can predict where and when these peak levels will occur. A large grid area also minimizes the possibility that receptor locations will be impacted by air parcels that have left the grid and then re-entered it due to a shift in wind during the time interval over which the model is run.

Too large a grid size, however, may also cause certain problems in gathering and manipulating data. For instance, a grid may extend into areas for which detailed spatially and temporally resolved emission estimates cannot be made due to lack of adequate information. This might be the case where one part of a grid lies within the jurisdiction of a metropolitan planning organization (MPO) and another part lies within an outlying, undeveloped jurisdiction. Detailed records and projections will probably be available for the metropolitan areas, but may not exist for the outlying area. Technical problems may also be encountered if various jurisdictions within a grid maintain information in different formats. For example, one area may maintain records for townships and use EPA's Emission Inventory System (EIS/P&R), whereas another area may maintain records for census tracts and use a locally developed data handling system that is incompatible with EIS/P&R.

While the grid area should be large in order to maximize coverage, individual grid cells should be small in order to optimize the spatial resolution of emissions. If the grid cells are too large, the model may lose precision in estimating ozone and precursor pollutant levels at receptor locations of interest. In addition, smaller grid cells provide better resolution of the impact of individual sources.

Of course, practical considerations limit how small each grid cell can be, just as they limit how large the overall grid can be. Resources are an important factor to consider. As the size of the grid or the number of grid cells increases, additional effort is required to collect the necessary emission data and to develop appropriate factors for allocating area source emissions. Also, computer costs increase significantly because of the increased core storage requirements associated with an increased number of grid cells.

In most model applications, a compromise is reached concerning the amount of area covered by the grid and the number of grid cells defined within the grid. A typical grid size in a number of urban areas where photochemical models have been run is about 50 to 150 km on each side, with grid spacing typically being about 2 to 5 km. Details concerning the development of the grid system are presented in Chapter 3.

2.2 DATA COLLECTION

When the grid system has been defined, the next important step in the compilation of a photochemical modeling emission inventory is the collection of appropriate emission data. Data are normally acquired separately for point sources, highway motor vehicles, and other area sources. It is assumed that a conventional annual, countywide emission inventory, as described in Volume I, already exists, and that additional data must be collected as a basis for assigning emissions to grid cells, for determining temporal distributions, and for estimating the proportions of VOC and NO_x to be assigned to species or classes required in the model.

2.2.1 EXISTING EMISSION INVENTORIES

Because many of the data requirements of the detailed emission inventory are quite resource-intensive, the inventorying agency should make use of whatever data and systems are already available. Thus, the agency should review the existing inventories, data handling systems, and planning models maintained by local agencies in order to determine what framework has already been established that may possibly be utilized in compiling the detailed emission inventory.

The existing emission inventory should first be reviewed to determine what source and emissions data are already available. Most urban locations have VOC and NO_x inventories at the level of detail of EPA's National Emission Data System (NEDS) or Emission Inventory System (EIS/P&R). If accurate, comprehensive and current, such inventories can provide much of the basic data needed for the detailed inventory. If not, the basic inventory should be updated prior to or during the initial stages of compiling the detailed inventory to be used for photochemical modeling.

The agency should also determine whether the existing inventory represents average annual emissions or seasonal emissions during the oxidant season. The seasonally adjusted inventory, if it exists, is more easily used as a starting point for the detailed modeling inventory. (Seasonal adjustment of the annual inventory is discussed in Volume I.)

The modeling region normally encompasses a number of counties; in rare cases, the entire modeling area is contained in one large county. Because most counties do not have rectilinear boundaries, portions of a county may extend beyond the boundaries of the modeling region. In this case, the existing countywide emission inventories must be adjusted to include only those emissions in the modeling region.

Local emission inventories usually incorporate point source records that contain most of the data (including stack parameters and operating information) needed for photochemical modeling. The only necessary point source data that are not generally included in such inventories are those dealing with VOC (and NO_x) species or classes and detailed hour-by-hour emission information. Likewise, most of the area-source countywide activity levels in local inventories can be used as the basis for apportioning area-source emissions to the grid cell level. Both temporal and spatial allocation factors are needed to apportion countywide area source emissions to the grid cell level.

The only important source category for which the basic countywide inventory does not ordinarily represent a good starting point is highway motor vehicles. In annual countywide inventories, highway motor vehicle emissions are often based either on countywide gasoline sales or on total vehicle miles traveled (VMT). These gross techniques do not provide the necessary spatial resolution for photochemical modeling, so it is desirable to obtain link-by-link traffic data for the area from a transportation planning agency.

2.2.2 PLANNING THE DATA COLLECTION EFFORT

The existing inventories should contain much of the required information on total emissions for the area of interest. The documentation provided in support of the countywide point source inventory (e.g., NEDS data) usually contains additional information on stack parameters. The data collection effort in support of the modeling inventory should be directed toward providing additional information to (1) define the spatial distribution and temporal variations in emissions from each source category, and (2) assign VOC and NO_x emissions to appropriate species classes. Ideally, emissions data (including VOC species) would be available for each source for each hour of any day selected for modeling. However, this degree of detail is, in practice, neither necessary nor practical for all sources, since it can require an inordinate amount of effort to secure such data, and since for many sources it would have little effect on the oxidant levels predicted by the photochemical model.

An important part of the data collection plan consists of deciding which apportioning information should be collected and which is unimportant (i.e., setting priorities). In a typical situation, highway motor vehicles, gasoline marketing and storage, solvent consumption, and power plants may account for much of the total VOC and NO_x emissions. The remaining VOC and NO_x emissions probably arise from a number of smaller sources, any of which individually has only a minor influence on predicted oxidant levels, even if small errors are made in allocating the emissions to the proper grid cells or in estimating their seasonal or diurnal variations. The existing basic inventory can tell the agency which sources are the most important emitters and, as a result, which should be surveyed or visited directly to obtain better spatially and temporally resolved emission data. Many sources are such minor VOC and NO_x emitters that little, if any, additional effort is warranted in gathering temporally and spatially resolved data regarding them.

Finally, it is essential that the inventory agency work closely with the metropolitan planning organization (MPO) or other planning agencies in the area to determine what transportation and land use planning models are being employed and what data they can provide that are directly useful to the inventory compilation effort. In general, in urban areas where comprehensive transportation and land use planning are performed, much of the information needed to determine highway motor vehicle emissions, to make projections, and to apportion emissions to the grid cell level will already be available.

2.2.3 INVENTORIES OF POLLUTANTS OTHER THAN VOC AND NO_x

The detailed inventory effort should be directed primarily toward obtaining accurate emission data for VOC and NO_x, because both of these precursor pollutants are extremely important in the photochemical production of ozone in urban atmospheres. Some photochemical models have the capacity to accept emissions data and generate air quality estimates for carbon monoxide (CO), sulfur oxides (SO_x), and total suspended particulates (TSP), as well. This capability is provided primarily to allow the user to study the effects of control strategies on ambient levels of these pollutants. Carbon monoxide, in addition, can serve as a nonreactive tracer material to test the reasonableness both of the mobile source inventory and of the basic dispersion mechanics of the model. However, emissions of CO, SO_x, and TSP have little effect on the ambient oxidant levels predicted by the photochemical model. Thus, although sources of these pollutants should be included in the photochemical modeling inventory, a great deal of expense is not warranted in developing spatially and temporally resolved emission estimates and projections for these sources if NO_x and VOC are not also emitted in significant quantities.

2.2.4 ELEVATED POINT SOURCE REQUIREMENTS

Some photochemical models assign emissions from point sources to elevated grid cells if they are characterized by a significant effective stack height. When this is the case, the emission inventory must include stack information (e.g., physical stack height and diameter, stack gas velocity, and temperature) for the major point sources in the area. The agency must therefore know whether the model it plans to employ requires these data. Certain stack information is usually included in the less detailed point-source emission inventories available in most urban areas. This information should, of course, be examined and utilized to the greatest extent possible in order to minimize additional costs to the detailed inventory effort.

2.3 SPATIAL RESOLUTION OF EMISSIONS

In order for photochemical models to provide spatially resolved predictions of ozone and various other pollutants at the grid cell level, they must be supplied with emission data that have the same degree of spatial resolution (i.e., that are resolved to the grid cell level.) The amount of effort required to resolve emissions at the grid cell level will vary depending on the type of source. Point source locations are typically known to within a fraction of a kilometer in existing, annual inventories; hence, it is easy to assign them to the appropriate grid cell. This assignment can either be made manually by overlaying an outline of the grid system onto a map showing point source locations, or a computer routine can be written to do it.

Area sources, on the other hand, require substantially more effort. There are two basic ways to determine area source emissions at the grid cell level. The most accurate (and most resource intensive) approach is to obtain area source activity level information directly for each grid cell. Airports are an example of a source category for which this may typically be done. The alternative approach, most commonly employed, is to apportion the countywide emissions from the annual inventory to the grid cell level by means of representative apportioning factors. This latter approach requires that surrogate indicators of emission levels (e.g., population, type of land use) be known or estimated for each grid cell and applied to the countywide emissions to yield grid cell emissions. The major assumption underlying the apportioning approach is that emissions from each area source behave spatially in the same manner as the surrogate indicator. For those area sources whose emissions must be apportioned from countywide totals, emphasis should be placed on developing accurate factors for the largest emitters. In most large urban areas, local planning agencies can provide the air pollution agency with detailed land use, population, or in some cases, employment statistics at the subcounty level. These data are commonly used for apportioning most of the area source emissions in the detailed photochemical modeling inventory.

Highway motor vehicle emissions, which are usually a large fraction of total VOC and NO_x emissions, are considered separately from other area sources in inventories used for photochemical modeling. Instead of using countywide VMT or gasoline sales to estimate highway vehicle emissions (as annual inventories typically do), urban transportation planning models are employed to generate VMT on an individual link basis. The emissions for each link are then assigned to the appropriate grid cells.

Planning, land use, and transportation models are already in use in many urban areas, and can provide the inventorying agency with much of the data necessary to allocate area source emissions and develop link-by-link emissions for highway motor vehicle sources. Moreover, such models are generally capable of developing forecasts for projection years. Thus, it is extremely important that local agencies (particularly MPO's) be contacted during the inventory planning process to determine what planning models are being utilized and how the data available from these models can be used in the emission inventory effort. Obviously, much redundant effort would be required on the part of the inventorying agency if it independently attempted to develop all the necessary information that should be available from the MPO. Moreover, any subsequent photochemical modeling results would likely be subject to challenge because of alleged nonconformity with other projections available to the public.

2.4 TEMPORAL RESOLUTION OF EMISSIONS

In order for photochemical simulation models to predict hourly concentrations of ozone and other pollutants, hour-by-hour estimates of emissions at the grid-cell level are needed. Several approaches can be used for providing the temporal detail needed in the inventory used in a photochemical model. The most accurate and exacting approach is to determine the emissions (or activity levels) for specific sources for each hour of a typical day in the time period being modeled. This approach is sometimes applicable to point sources but is often impractical.

An alternative approach is to develop typical hourly patterns of activity levels for each source category, and then apply these to the annual or seasonally adjusted emissions to estimate hourly emissions. This approach is commonly employed for area sources, including highway motor vehicles, and is usually used for all but the largest point sources.

Usually, the photochemical air quality model, and therefore the emission inventory, is applied to the season of the year in which weather is most conducive to oxidant formation; for most locations, this means the summer and near-summer months (i.e., April through October).

Similarly, emissions are usually chosen to represent the day of the week on which polluting activities are at a maximum, normally a weekday. In some cases it can be useful, especially for validation studies, to simulate weekend conditions when automotive and industrial emission levels are reduced. For this purpose a weekend inventory will be needed, and additional temporal pattern information will have to be obtained pertaining to weekend days. Generally, however, it is not recommended that the agency compile a weekend inventory unless (1) significant reductions or changes in emission patterns are expected, and (2) the same inventorying procedures can be used as for weekdays, so that any resulting changes in predicted ambient ozone levels can be attributed to actual changes in precursor pollutant levels and patterns rather than simply to changes in methodologies. The latter will not be possible in many areas for highway vehicles as transportation models are based on information (e.g., travel pattern surveys) that is applicable only to weekday situations. If the agency plans to utilize the model to estimate ambient concentrations of various pollutants for time periods other than the oxidant season, additional seasonal information may be required.

2.5 VOC (AND NO_x) SPECIES ALLOCATION

Because photochemical models are intended to simulate actual photochemistry, they utilize different chemistry for various types of VOCs and require specific information as to the proportions of these various types in the VOC emissions. For this reason, VOC emission totals must be disaggregated into subtotals for various VOC classes. In addition, NO_x emissions may have to be distributed into NO and NO_2. (Some models do not require an NO_x breakdown because they assume all NO_x emissions to be NO.) Literally hundreds of individual chemical compounds typically compose the total VOC emissions in an urban area. No photochemical model considers each organic compound individually; rather, classes of VOC are defined that behave similarly in photochemical reactions. One classification scheme distinguishes four classes of compounds: paraffins, olefins, aromatics, and aldehydes. Another distinguishes six classes and is based on the presence of certain types of carbon bonds in each VOC molecule. Other classification schemes employ different numbers and types of VOC classes. Typically, three to six classes of VOC are distinguished by various photochemical models. (See Appendix A for details on individual models.)

The standard procedure for allocating VOC to classes is to assume that VOC emissions from each type of source contain a certain percentage of each class of compound. This procedure is the easiest of several procedures that can be followed for allocating VOC emissions as the same VOC distribution is assumed to apply to each facility within a given source category.

In some instances, source-specific VOC species data are known for certain individual facilities (e.g., through source tests or material composition considerations), and the agency may prefer to use these in the detailed inventory rather than an assumed VOC species distribution. Generally, however, most industries cannot provide reliable VOC (and NO_x) species data or accurately apportion their emissions into appropriate classes, in which cases generalized VOC and NO_x distributions must be assumed for various source categories. Generalized VOC and NO_x "split factors" are available in the literature for this purpose (as is described in Chapter 7.)

A potential problem when using split factors to apportion VOC and NO_x into classes is that the source classification scheme (i.e., source category breakdown) employed in the inventory will probably not be directly compatible with the available split factor classification scheme in all cases. For example, the inventory may not distinguish between automotive exhaust and evaporative emissions, whereas VOC split factors are typically available for each of these automotive emission components (and may be significantly different in some classification schemes.) As another example, many VOC classification schemes do not distinguish between different types of fuel combustion and boilers, yet most inventories do.

Hence, it is important in the planning stages that the agency examine the split factors available for use and compare the classification thereof with the source classification scheme of the basic inventory. If serious inconsistencies are apparent for the more important VOC and NO_x source categories, the agency may need to consider modifying the classification scheme to minimize any error that may result. The agency should be cautioned that if it chooses to alter the inventory source classification scheme, the resources required may be significant and should be carefully assessed prior to instituting such a change.

2.6 EMISSION PROJECTIONS

Regardless of what ozone source/receptor relationship or model is employed, projection inventories are needed in order for the agency to determine whether a given area will achieve or exceed the ozone standard in future years. There are basically two types of projections: baseline projections and control strategy projections. Baseline projections are estimates of future year emissions that take into account both expected growth in an area and air pollution control regulations that are in effect at the time the projections are made.* Control strategy projections, on the other hand, are estimates of future year emissions that also include the expected impact of changed or additional control regulations.

In many respects, the detailed projection emission inventory used in a photochemical model will be the same as the baseline projection inventory of annual, countywide emissions compiled for use in EKMA or rollback. That is, the same source categories and pollutants will be emphasized; and the same emission factors, activity levels, and control device data will be utilized. Hence, just as in the base year case, the annual, countywide projection inventory may serve as a good starting point for the projection inventory used in a photochemical model. However, as has been discussed in the preceding sections, additional considerations are required to incorporate the spatial and temporal resolution needed by photochemical models and to apportion VOC (or NO_x) into classes. These considerations are highlighted below as they specifically relate to projection inventories:

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* Certain provisions in existing control regulations may take effect only at some future date. Baseline projections include the effects of these expected changes.

- Attention should be given to spatial changes in emissions from the base year to projection years. Changes in point source emissions due to growth or control measures should be associated with specific locations within the modeling area, i.e., at either new or existing facilities. In this regard, it is especially critical to pinpoint the location of any large point sources of VOC or NO_x that will be coming on line. Apportioning factors for apportioning area sources should reflect future land use patterns, employment, population, etc. Highway vehicle emission inventories should reflect changes in highway networks and changing driving patterns.
- Attention should be given to changes in temporal emission patterns. Any anticipated changes in hourly, daily, or seasonal operating patterns between the base year and projection years should be reflected in the projection inventories.
- To the extent that VOC (and NO_x) split factors are expected to change from the base year to any projection year, such changes should also be incorporated.

Generally, of these three considerations, information will be most readily available concerning changes in spatial distribution. This is because the air pollution agency should know where large, new point sources will be located (at least in near-term projections) and because highway vehicle and area source emission patterns will directly reflect changes in land use, employment, and transportation data supplied by local planning agencies. Typically, most of the temporal patterns and VOC (and NO_x) split factors will not be changed from the base year inventory either because no changes are expected or because no data will be available to support any changes. These considerations are discussed in more detail in succeeding chapters.

Of course, in some instances, baseline projection inventories of annual, countywide emissions for the particular years of interest will not be available for use as starting points for the detailed, photochemical modeling inventories. Or, in other cases, the projection inventories that do exist may not reflect all of the growth and control scenarios that the agency may wish to evaluate with the photochemical model. In these situations, the agency will have to devote resources to the development of projection year inventories. Specific recommendations for making baseline projections are also discussed in the following chapters of this volume. However, the following general considerations should be kept in mind from the outset of the inventory planning stages.

1. To a large extent, projection inventories will be based on forecasts of industrial growth, population, land use, and transportation. The air pollution agency should not attempt to make these forecasts itself, but rather should rely on the local MPO or other planning agencies to supply them. This course has several profound advantages. First, it would be extremely costly for the air pollution agency to duplicate the forecasts made by other planning agencies. Second, the air pollution agency needs to base its emission projections on the same forecasts that other governmental planning agencies are utilizing. This consistency is necessary to foster the credibility of any proposed control programs that are based on these emission projections.
2. It is desirable to know what control strategies are being considered in the modeling area in order to design control strategy projection inventories to reflect these strategies. This consideration may influence the type of data collected as well as the structure of the inventory itself. As an example, if the agency wants to test the effect of applying Stage I controls only to service stations above a particular size cutoff, it may be desirable to treat these particular stations as point sources rather than lumping them in with a general service-station area-source category.
3. It is very important that all projected emissions for future years be based on the same methodologies and computation principles as the base year emissions. For example, if a traffic model is used for estimating travel demand for the

base year, the same traffic model should be applied to estimate travel demand for projection years. Use of the same methodology assures consistency between base year and projection year emission estimates, and prevents the possibility of spurious inventory differences based solely on changes in methodology.

4. Projection inventories will always be open for attack because of their somewhat speculative nature. The technical credibility of emissions projections will be a function of their reasonableness, the amount of research and documentation of assumptions, and the procedures or methodologies used to make the projections. Some degree of uncertainty will always accompany emission projections. This fact should be acknowledged openly. The art of projecting emission inventories is not eliminating uncertainty, but learning how to minimize uncertainty. Internal and external review of emission inventory projections will improve their technical quality and enhance their credibility.

2.7 DATA HANDLING

Due to the large amount of data that must be gathered and stored in the inventory effort and to the complexity of developing spatially and temporally resolved emission projections, a computerized data handling system is usually a necessity in a photochemical modeling effort.

Ideally, it is desirable to computerize as many data handling functions as possible, because the agency can then devote more manpower resources to collecting and analyzing the inventory data. The computerization of each function requires that the agency develop a flow chart of the entire data handling operation, from the initial gathering of inventory data to the final development of a data file (or "modeler's tape") that is in the input format of the photochemical model being used.

Many of the data handling functions that are necessary in both basic and detailed emission inventories (e.g., data storage) are described in Volume I of this document. Several additional data handling requirements arise during the development of the detailed inventory due to the need for spatial and temporal resolution of the emission data and the need to disaggregate VOC and NO_x emissions.

Spatial resolution is provided by allocating area source emissions to grid cells using appropriate apportioning factors. This step is usually computerized because of the large numbers of factors and calculations involved.* Likewise, computerized programs are generally used to assign point source and highway motor vehicle emissions to the appropriate grid cells.

Temporal resolution is often provided for area and line sources by developing typical hourly activity patterns for each major source category. For many point sources, hourly activity levels can be reasonably inferred from the operating information that is typically supplied in annual, countywide inventories. In either case, relatively simple algorithms can be developed and computerized to provide the necessary temporal resolution for the detailed inventory.

VOC emissions are usually disaggregated into species classes through the use of an appropriate species distribution for each source category. NO_x emissions are either assumed to be all NO or are split into NO and NO_2. The allocation of VOC and NO_x emissions into classes involves straightforward calculations that should likewise be computerized.

A major data handling function involved in compiling a detailed inventory is the development of emission projections. Growth is typically accounted for by adjusting base year emissions in accordance either with projected changes in the emissions themselves or with changes in appropriate surrogate indicators of growth (e.g., earnings, population, land use, and employment). Control regulation and strategies are reflected in an inventory by adjusting activity levels, control device efficiencies, or emission factors, as appropriate. The data handling system should be designed to automate the development of growth and control-strategy projections as much as possible, thus minimizing the amount of manual effort needed each time a different scenario is modeled.

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* The actual determination of these apportioning factors, however, often requires a great deal of manual effort. Refer to Subsection 6.2, "General Methodology for Spatial Resolution," for details.

The final inventorying activity is the generation of the "modeler's tape" which serves as the interface between the emission inventory and the photochemical model. Because each model requires a special computerized format for the inventory data, utility programs will be necessary to convert the emission inventory file to the format of the modeler's tape.

Of course, there may be compromises between a completely computerized data handling system and manually carrying out all data handling functions. Certain functions, such as determining area source apportioning or growth factors, may be difficult to automate without developing extremely large and complex sets of programs and files. Thus, during the planning stages, the agency must carefully review the data handling flow chart to determine which activities can be done most efficiently by computer and which functions are best performed manually. Data handling is further discussed in Chapter 8.

2.8 MANPOWER REQUIREMENTS

The amount of manpower and types of expertise are the necessary considerations in planning an emission inventory for a photochemical model. Depending on the status of the existing inventory and the amount of detail required, emission inventories for use in a photochemical model can require from 500 to 5,000 manhours. The low estimate is for a case in which a gridded or very complete countywide inventory already exists, and the region is dominated by only a few major types of sources. The high estimate is for a case in which little or obsolete inventory information is available, and the region has many types of significant sources. This case would require a detailed analysis of all significant sources and much individual contact with managers of specific sources.

In addition to those usually engaged in compiling the inventory, the agency should enlist the services of (1) a photochemical modeling specialist familiar with the operation and the VOC species classes of the particular photochemical model to be used, (2) a computer programmer to plan the storage and manipulation of the large amounts of emission data needed, and (3) an urban or regional planner to analyze transportation and land use data from local planning agencies and to assist the air pollution control agency in making emission projections.

2.9 OVERVIEW OF EMISSION INVENTORY PROCEDURES

The remaining chapters of this document discuss the detailed "how-to" procedures necessary for producing an emission inventory for use in a photochemical air quality simulation model. Specific procedures are described for (1) defining the grid system, (2) collecting and compiling source and emissions data from point, highway motor vehicle, and other area sources, (3) allocating VOC (and NO_x) emission data into species classes, and (4) data handling. For a perspective of the overall emission inventory process, an overview is presented in Figure 2-1 of the procedures necessary to produce a photochemical modeling inventory. Each box in Figure 2-1 has a chapter and section indicated inside that refers the reader to where each inventory activity is discussed in detail in this document. (Procedural options for highway motor vehicle data collection and analysis are reviewed more specifically in Section 5.3).

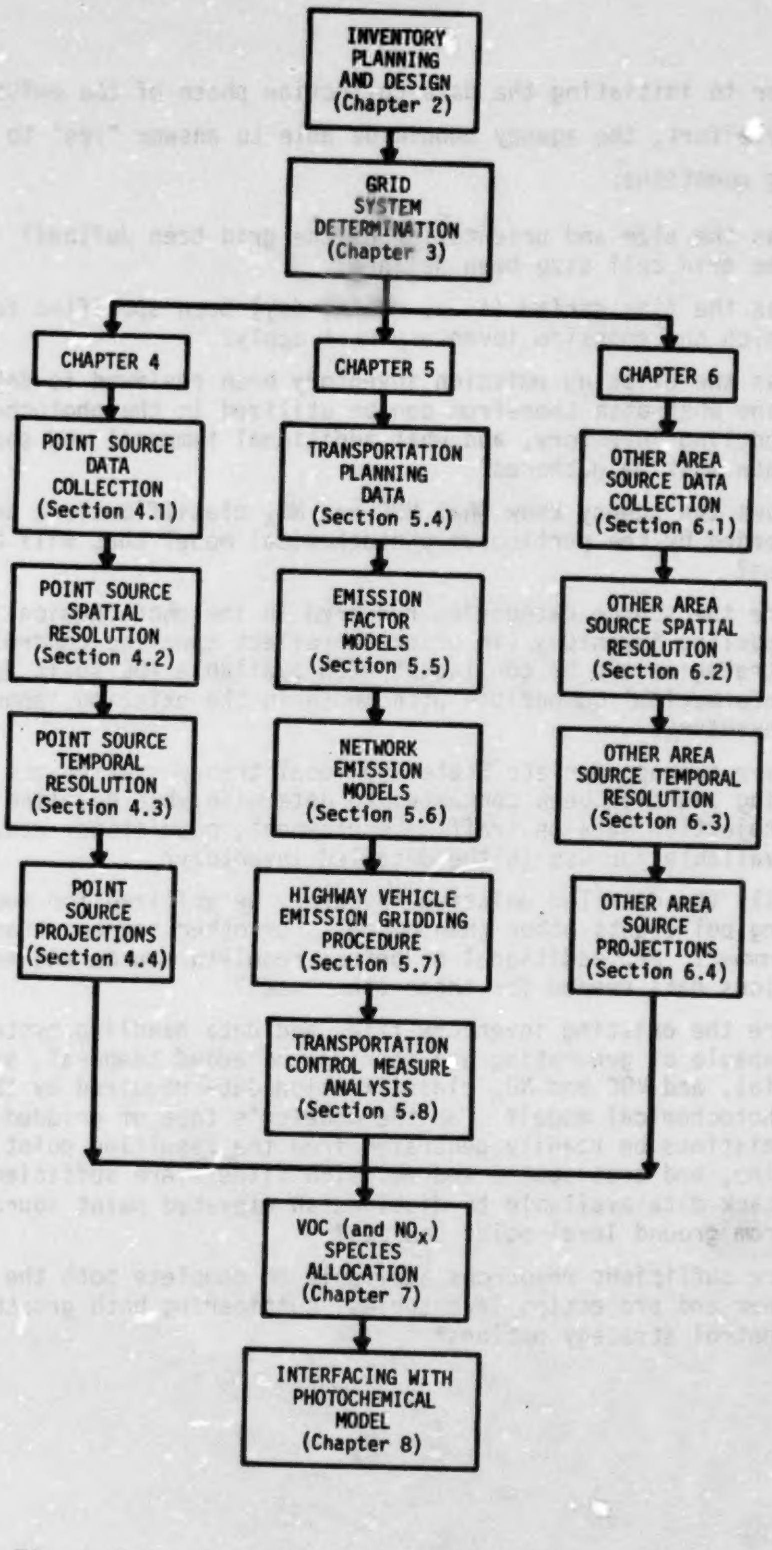
INVENTORY PLANNING AND DESIGN (Chapter 2)
GRID SYSTEM DETERMINATION (Chapter 3)
CHAPTER 4
CHAPTER 5
CHAPTER 6
POINT SOURCE DATA COLLECTION (Section 4.1)
POINT SOURCE SPATIAL RESOLUTION (Section 4.2)
POINT SOURCE TEMPORAL RESOLUTION (Section 4.3)
POINT SOURCE PROJECTIONS (Section 4.4)
TRANSPORTATION PLANNING DATA (Section 5.4)
EMISSION FACTOR MODELS (Section 5.5)
NETWORK EMISSION MODELS (Section 5.6)
HIGHWAY VEHICLE EMISSION GRIDDING PROCEDURE (Section 5.7)
TRANSPORTATION CONTROL MEASURE ANALYSIS (Section 5.8)
OTHER AREA SOURCE DATA COLLECTION (Section 6.1)
OTHER AREA SOURCE SPATIAL RESOLUTION (Section 6.2)
OTHER AREA SOURCE TEMPORAL RESOLUTION (Section 6.3)
OTHER AREA SOURCE PROJECTIONS (Section 6.4)
VOC (and NO$_x$) SPECIES ALLOCATION (Chapter 7)
INTERFACING WITH PHOTOCHEMICAL MODEL (Chapter 8)

Figure 2-1. Overview of Emission Inventory Procedures

Prior to initiating the data collection phase of the emission inventory effort, the agency should be able to answer "yes" to the following questions:

- Has the size and orientation of the grid been defined? Has the grid cell size been defined?
- Has the time period (i.e., month, day) been specified for which the emission inventory must apply?
- Has the existing emission inventory been reviewed to determine what data therefrom can be utilized in the photochemical modeling inventory, and what additional temporal and spatial data must be gathered?
- Does the agency know what VOC and NO_x classifications are needed by the particular photochemical model that will be run?
- Are the source categories required in the photochemical modeling inventory (in order to reflect specific control strategies and be consistent with available VOC split factor information) compatible with those in the existing, annual inventory?
- Have the appropriate State and local transportation and planning agencies been contacted to determine what baseline and projection data on traffic, employment, population, etc., are available for use in the detailed inventory?
- Will the detailed emission inventory be utilized for modeling pollutants other than ozone? For other seasons than the summer? Are additional or better-resolved source and emissions data needed for these other uses?
- Are the existing inventory files and data handling systems capable of generating and storing the added temporal, spatial, and VOC and NO_x classification data required by the photochemical model? Can the modeler's tape of gridded emissions be readily generated from the resulting point, line, and area source and emission files? Are sufficient stack data available to distinguish elevated point sources from ground level point sources?
- Are sufficient resources available to complete both the base year and projection inventories, considering both growth and control strategy options?

3.0 DETERMINATION OF THE GRID SYSTEM

3.1 CHOOSING AN APPROPRIATE GRID SYSTEM

A primary decision, which will influence all subsequent phases of the emission inventory process, is the determination of the grid system. Photochemical models require that emissions be localized in terms of a number of individual square grid cells of equal size which are contained within a rectangular boundary, or grid. As an example, Figure 3-1 shows a map of the vicinity of Tulsa, Oklahoma, with an emission inventory grid system superimposed. The gridded area covers a rectangle 50 km wide by 124 km long; it contains 1,550 individual square grid cells, with a grid spacing unit of 2 km. Since emissions must be determined for each grid cell, it is extremely important to develop an appropriate grid system at the start of the emission inventory effort.

3.1.1 AREA COVERED BY THE GRID SYSTEM

As shown in Figure 3-1, the gridded area is normally rectangular. Although some models may accept an irregularly shaped grid boundary, it is recommended, for the sake of simplicity and ease in locating grid cells, that a rectangle be used for the boundary of the emissions area. The forcing of a rectangular boundary around an irregularly shaped city means that many of the peripheral grid cells may contain zero emissions. For example, cities on the coast usually have portions of the ocean included within the rectangular grid boundary.

The area covered by the emission grid should be large enough to (1) include all major emission sources in the region, (2) encompass areas of future industrial and residential growth, (3) include as many pollutant monitoring stations as possible, and (4) incor-

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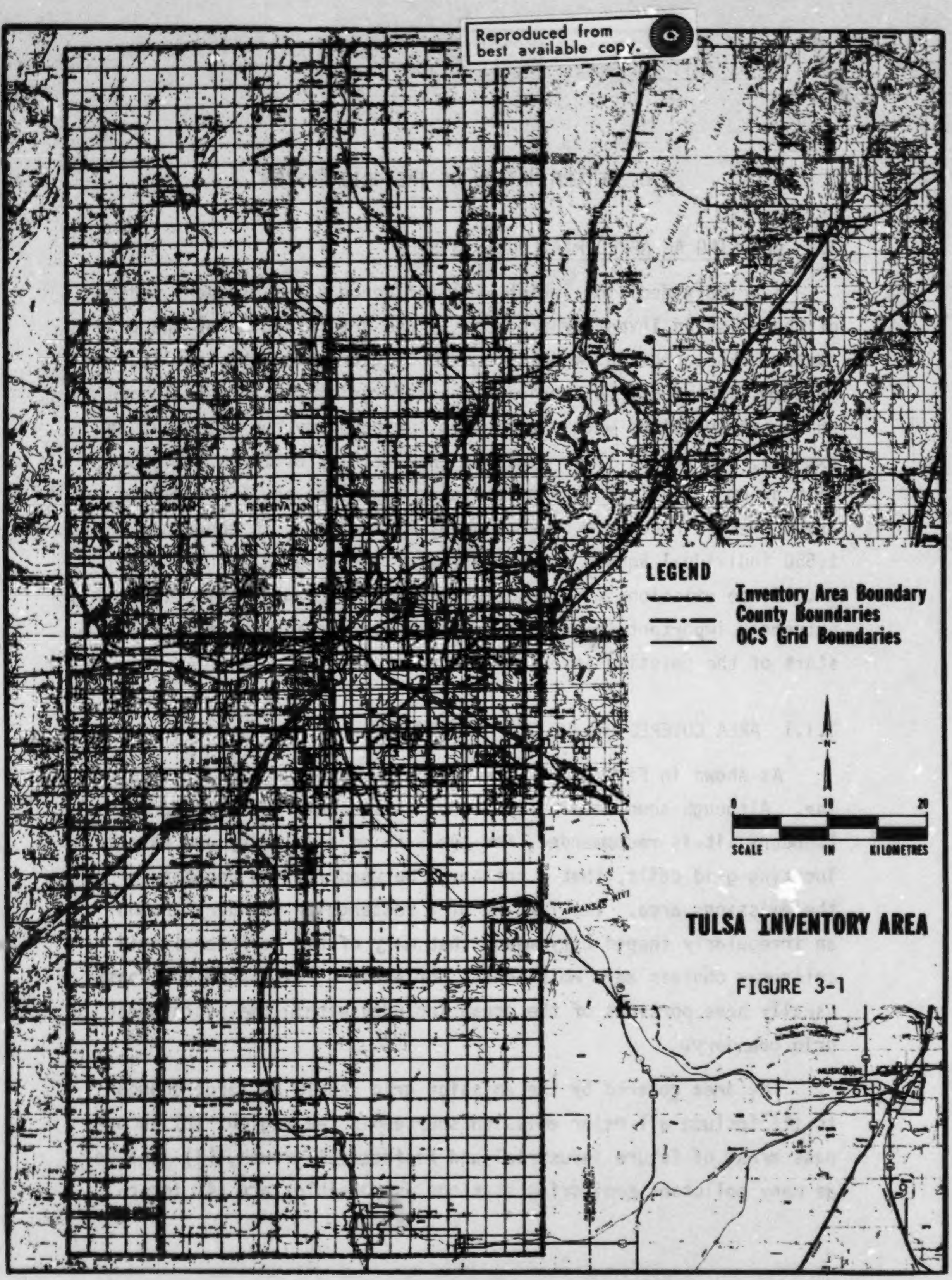
LEGEND
Inventory Area Boundary
County Boundaries
OCS Grid Boundaries
N
0
10
20
SCALE
IN
KILOMETRES
INDIAN
RESERVATION
ARKANSAS RIVE
LAKE
MUSKOGEE

TULSA INVENTORY AREA

FIGURE 3-1

porate downwind receptor sites of interest. In this latter regard, the agency should extend the grid to encompass areas downwind of the urban area where peak ozone levels generally occur. Thus, the selection of the grid area to be covered by the emission inventory is not a simple one, but rather an interdisciplinary decision which will involve discussions with planning agencies, air pollution control agencies, meteorologists, and photochemical modeling specialists. Modeling specialists know that some photochemical models may be very sensitive to the levels of ambient concentrations which must be assumed along the grid boundaries.[1] Thus, in order to assume relatively clean "background" ambient air concentrations along the boundaries of the modeling region, the total area for the emission grid should extend into areas with little or no emissions. Of course, in certain areas (e.g., the Northeast United States), pollutant transport from nearby urban areas may preclude the possibility of a clean background along any boundaries that may be chosen.

In some cases, the exact area to which a photochemical model will be applied may not be initially known, due to uncertainties about future land use or the effect of meteorological conditions. In these cases, an emission grid as large as possible is desirable, so that a smaller area can be chosen for photochemical modeling within the emission grid. Thus, the emission grid can be larger than the actual grid used for modeling. Generally, however, it is recommended, for most efficient use of time and resources, that the emission grid and the modeling grid coincide. This optimum grid area is a result of close cooperation between inventory personnel, planning agencies, and modeling experts.

3.1.2 GRID CELL SIZE

The degree of spatial resolution of the emissions is also a very important factor and must be decided during the planning stages of the inventory effort. The choice of an appropriate grid spacing depends on the overall modeling objectives, the total area of interest, the amount of manpower available, and the cost of running the photochemical model.

Ideally, it is desirable to have a very fine grid spacing (e.g., 1 km) for accurately representing emissions from a variety of sources in different locations. However, if a very large area is to be covered, this level of resolution becomes unmanageable. For example, if the region of interest is 100 km by 100 km, a grid cell size of 1 by 1 km would result in a total of 10,000 individual cells for which emissions would have to be calculated. For such a large area, it is unlikely that such fine resolution would result in appreciable improvement in predicted ozone levels over the entire region relative to a larger grid spacing, such as 5 km. The major advantage of the larger grid cell size is that the total number of grid cells would be considerably less (400 as opposed to 10,000), and both the computer and manpower costs would be significantly reduced.

Compromise between the maximum amount of area covered and the smallest possible grid cell size normally results in grid spacing being from 2 to 5 km in urban-scale photochemical models. Since oxidant formation occurs over an appreciable amount of time and space, grid spacing smaller than 1 km is not recommended. Also, grid cells smaller than 1 by 1 km would exceed the resolution of some of the transportation modeling data typically generated by transportation agencies as well as much of the area source apportioning factor data. On the other hand, grid spacing larger than 10 km would probably mask the effect of individual sources, because all photochemical models assume that emissions are averaged over the entire grid cell area (i.e., when using 10 km grid cells, all emissions in any cell, including individual point sources, are assumed to be uniformly emitted from the entire 100 km^2 grid cell area). This type of dilution may lead to inaccuracies in using the photochemical model.

If a specific photochemical model and grid system have not been chosen when the inventory is compiled, it is recommended that, if possible, the smallest grid cell size under consideration be used. Aggregation to larger grid cells is then a simple procedure of combining an integral number of grid cells. Thus, the initial emission grid spacing can be smaller than the actual grid spacing subsequently used for modeling. However, resource considerations may preclude such fine emission resolution if the inventory involves a very large grid area. It is important to avoid compiling the inventory for a grid spacing larger than is subsequently considered desirable for photochemical modeling. It is very difficult to allocate emissions to a finer grid cell network once the inventory is completed, but it is easy to aggregate smaller grid cells to form larger ones. The optimum situation is for the emission grid cells to coincide with the grid cell size used for photochemical modeling.

An important consideration in determining the grid system area and the size of individual grid cells is to examine the overall objectives for using the photochemical model. If control strategies are to be evaluated over a fairly large area (e.g., an Air Quality Control Region), then a fairly large grid area is necessary and a fairly coarse emission resolution may be acceptable. If control strategies are to be evaluated for a fairly small area (e.g., an individual city), then a relatively fine emission resolution may be warranted. For the modeling objective of evaluating the air quality impact of a proposed new source, a relatively fine emission resolution would probably be necessary, since very large grid cells may mask the effect of the individual new source. Thus, before a final grid system is chosen, a photochemical modeling specialist should be consulted regarding the effect of emission resolution on modeling predictions.

3.2 MAP GRIDDING PROCEDURES

3.2.1 UTM COORDINATE SYSTEM

When a grid system has been decided upon, it will be necessary to overlay this grid system on an appropriate map in order to determine which sources lie within what grid cells, and to determine area source apportioning factors for each grid cell. The recommended coordinate system is the Universal Transverse Mercator (UTM) system,[2] which is used in the NEDS and EIS/P&R emission data systems to reference all point source locations. It is very important to use the UTM coordinate system from the outset in the development of the grid system, because changing from one coordinate system to another is usually very difficult. For example, changing from latitude and longitude coordinates to UTM coordinates is a difficult procedure involving computerized calculations.

The most accurate maps normally available for gridding purposes are those produced by the U.S. Geological Survey (USGS), which provides topographic maps in different scales for all sections of the United States. The more recent USGS maps have a 10 km UTM grid system superimposed on them; older USGS maps simply have blue tick marks along the edges that represent the UTM coordinate system.

3.2.2 ORIENTING THE GRID SYSTEM

It is important to base a master grid system on a USGS map, since other maps (e.g., highway maps) may have considerable inaccuracies. The technique normally used for overlaying a grid system on a map is to position a transparent plastic sheet over the map and to draw the gridded area on the plastic sheet.[3,4] Instead of positioning the transparent sheet over the map and then drawing the grid cell boundaries, it is easier to first draw the rectilinear grid system to scale on the plastic sheet. The gridded plastic sheet can then be superimposed on the map and the grid system can be conveniently oriented.

The grid system should be aligned so that the grid lines essentially run north-south and east-west.* This is not necessary for running the photochemical model, but is recommended for the sake of convenience in defining locations on the grid and to enhance compatibility of the inventory with meteorological data.

Likewise, for the sake of convenience, the grid should be oriented so that the grid cell boundaries coincide with the UTM kilometer grid lines (i.e., the grid cells are defined by whole UTM kilometer numbers.)** This simplifies locating a particular grid cell and allocating point sources to the appropriate grid cells.

3.2.3 PROBLEMS IN GRIDDING

In addition to making a master grid on a USGS map, it is often necessary to transfer the grid system to other maps such as detailed street, land-use, or population-density maps. This is necessary because many of the features that need to be used in the inventory effort will not be identified on the USGS maps. A major problem is that other maps may not be as dimensionally accurate or on the same scale as the USGS map. Thus, while attempting to align the master grid on a land-use map, one may notice that certain major features are located in slightly different grid cells than on the USGS map. If the scale of the auxiliary map is not quite accurate, it may be possible to extend or decrease the map grid line dimensions so that most grid cells correspond to those on the USGS map. In many cases, the best procedure is to align the main urban area as correctly as possible. Inaccuracies in the outer portions of the grid are less important because fewer emissions normally occur in the outlying grid cells.

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* Within the region typically modeled in most urban areas, a grid system based on UTM coordinates will largely meet this criterion.

** Obviously, if nonmetric grid cell dimensions (e.g., miles) are used, this will not be possible.

Although USGS maps are dimensionally accurate, they are not always detailed enough to locate particular sources. This is partly because the most detailed scale of any USGS map is only 1:24,000, and partly because some of the available USGS maps are old (e.g., circa 1950) and so do not show current street locations. Thus, it is usually necessary to obtain more detailed street maps covering the entire area of interest in order to accurately locate specific sources. If possible, it is desirable to have all street maps on the same scale, so that a number of them can be combined to show a larger area. The task of overlaying the grid system on the individual street maps is a difficult one because street maps rarely have UTM coordinates; thus, care must be used in positioning the grid system according to the major street arteries shown on the USGS map.

References for Chapter 3.0

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2. Grids and Grid References, Technical Manual No. TM 5241-1, U.S. Department of the Army, Washington, DC, June 1967.

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4.0 POINT SOURCE EMISSIONS

4.1 DATA COLLECTION

As discussed briefly in Chapter 2.0, a good starting place for point source inventory used in a photochemical modeling application is the existing, basic point source inventory prepared by the State or local agency. Procedures for the preparation of the basic point source inventory for use in less detailed source/receptor relationships are outlined in Volume I of this series.[1] State and local point source inventories can be obtained in standardized formats from the State, if the State uses EPA's Emission Inventory System (EIS/P&R), and from the National Emission Data System (NEDS).

An example of a NEDS point source record is shown in Figure 4-1. Three types of information are coded for each facility. First, identifying information is associated with each level of data to allow the user of the system to arrange, select, and manipulate the inventory data to his needs. This includes plant and point identification numbers, UTM grid coordinates, plant names and addresses, and key contacts. The second type of information is process information, including equipment descriptors (e.g., source classification or basic equipment codes), stack parameters, control device information, operating rates, and fuel characteristics. The third type of information is on emissions from each process within the facility. The primary pollutants of concern from an oxidant standpoint, of course, are VOC and NO_x; annual estimates of these should be available from the basic inventory.

In relation to point sources, the existing, basic inventory resulting from the procedures in Volume I will fulfill most of the

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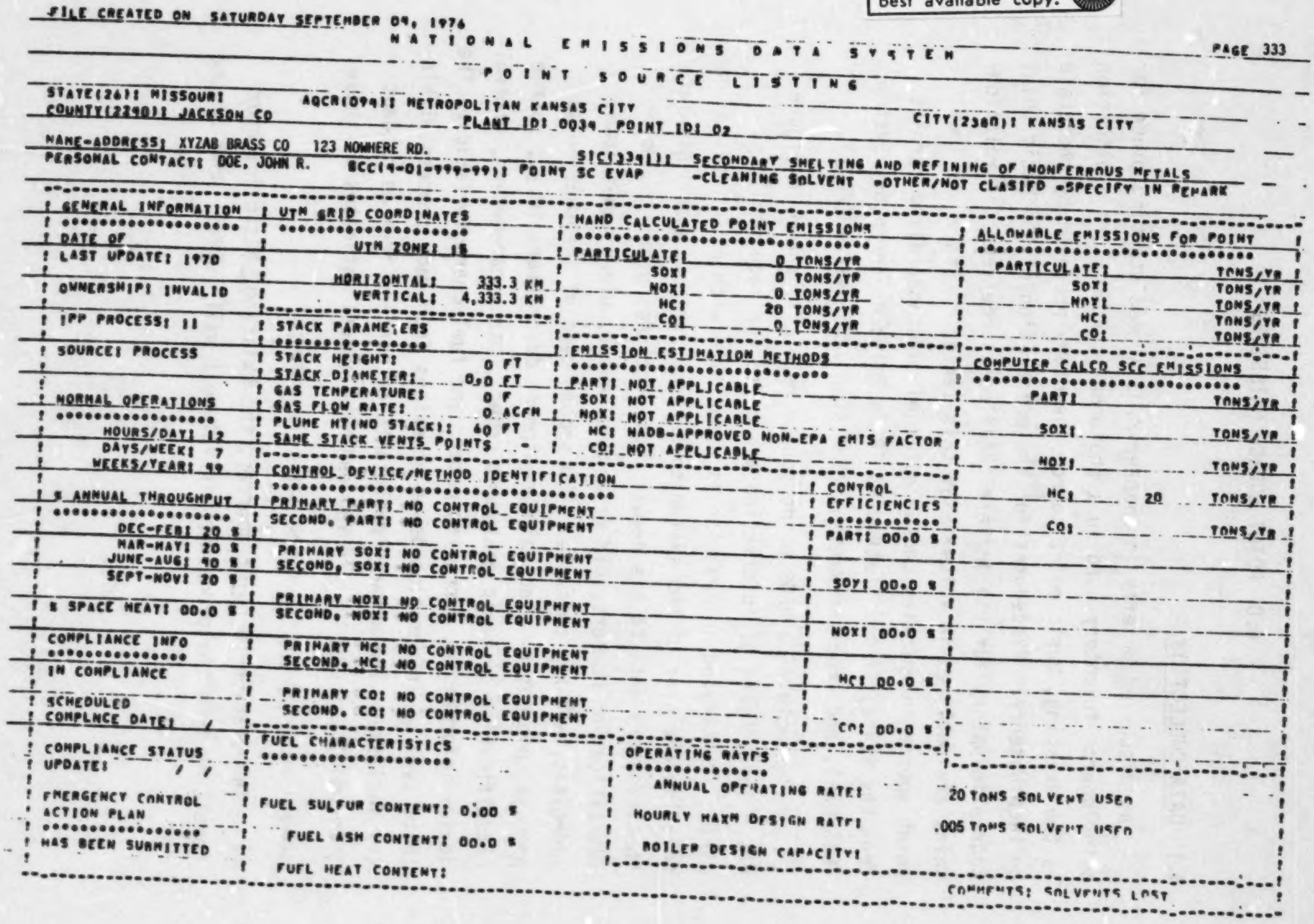

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FILE CREATED ON  SATURDAY SEPTEMBER 04, 1976
                       N A T I O N A L   E M I S S I O N S   D A T A   S Y S T E M                                   PAGE 333
                                  P O I N T   S O U R C E   L I S T I N G
STATE(26): MISSOURI          AQCR(094): METROPOLITAN KANSAS CITY
COUNTY(2240): JACKSON CO                                                              CITY(2380): KANSAS CITY
                                       PLANT ID: 0034  POINT ID: 02
NAME-ADDRESS: XYZAB BRASS CO   123 NOWHERE RD.
PERSONAL CONTACT: DOE, JOHN R.    SCC(4-01-999-99): POINT SC EVAP   SIC(3341):  SECONDARY SMELTING AND REFINING OF NONFERROUS METALS
                                                                    -CLEANING SOLVENT  -OTHER/NOT CLASIFD -SPECIFY IN REMARK
-------------------------------------------------------------------------------------------------------------------------------
! GENERAL INFORMATION   ! UTM GRID COORDINATES           ! HAND CALCULATED POINT EMISSIONS       ! ALLOWABLE EMISSIONS FOR POINT    !
! ********************  ! ********************           ! ******************************        ! ******************************   !
! DATE OF               !          UTM ZONE: 15          ! PARTICULATE:          0 TONS/YR       !   PARTICULATE:          TONS/YR  !
! LAST UPDATE: 1970     !                                !        SOX:           0 TONS/YR       !          SOX:           TONS/YR  !
!                       !      HORIZONTAL:    333.3 KM   !        NOX:           0 TONS/YR       !          NOX:           TONS/YR  !
! OWNERSHIP: INVALID    !        VERTICAL:  4,333.3 KM   !         HC:          20 TONS/YR       !           HC:           TONS/YR  !
!                       !--------------------------------!         CO:           0 TONS/YR       !           CO:           TONS/YR  !
! IPP PROCESS: 11       ! STACK PARAMETERS               !---------------------------------------!----------------------------------!
!                       ! ****************               ! EMISSION ESTIMATION METHODS           ! COMPUTER CALCD SCC EMISSIONS     !
! SOURCE: PROCESS       ! STACK HEIGHT:           0 FT   ! ***************************           ! ******************************   !
!                       ! STACK DIAMETER:       0.0 FT   ! PART: NOT APPLICABLE                  !         PART:           TONS/YR  !
!                       ! GAS TEMPERATURE:        0 F    !  SOX: NOT APPLICABLE                  !                                  !
! NORMAL OPERATIONS     ! GAS FLOW RATE:          0 ACFM !  NOX: NOT APPLICABLE                  !          SOX:           TONS/YR  !
! ****************      ! PLUME HT(NO STACK):    60 FT   !   HC: NADB-APPROVED NON-EPA EMIS FACTOR !                                !
!     HOURS/DAY: 12     ! SAME STACK VENTS POINTS    -   !   CO: NOT APPLICABLE                  !          NOX:           TONS/YR  !
!      DAYS/WEEK:  7    !----------------------------------------------------------------------!                                  !
!     WEEKS/YEAR: 49    ! CONTROL DEVICE/METHOD IDENTIFICATION                 ! CONTROL         !           HC:      20   TONS/YR  !
!                       ! ************************************                 ! EFFICIENCIES    !                                  !
! % ANNUAL THROUGHPUT   ! PRIMARY PART: NO CONTROL EQUIPMENT                   ! ************    !           CO:           TONS/YR  !
! ******************    ! SECOND. PART: NO CONTROL EQUIPMENT                   ! PART: 00.0 %    !                                  !
!      DEC-FEB: 20 %    !                                                      !                 !                                  !
!      MAR-MAY: 20 %    !  PRIMARY SOX: NO CONTROL EQUIPMENT                   !                 !                                  !
!     JUNE-AUG: 40 %    !  SECOND. SOX: NO CONTROL EQUIPMENT                   !  SOX: 00.0 %    !                                  !
!     SEPT-NOV: 20 %    !                                                      !                 !                                  !
!                       !  PRIMARY NOX: NO CONTROL EQUIPMENT                   !                 !                                  !
! % SPACE HEAT: 00.0 %  !  SECOND. NOX: NO CONTROL EQUIPMENT                   !  NOX: 00.0 %    !                                  !
!                       !                                                      !                 !                                  !
! COMPLIANCE INFO       !   PRIMARY HC: NO CONTROL EQUIPMENT                   !                 !                                  !
! ***************       !   SECOND. HC: NO CONTROL EQUIPMENT                   !   HC: 00.0 %    !                                  !
! IN COMPLIANCE         !                                                      !                 !                                  !
!                       !   PRIMARY CO: NO CONTROL EQUIPMENT                   !                 !                                  !
! SCHEDULED             !   SECOND. CO: NO CONTROL EQUIPMENT                   !                 !                                  !
! COMPLNCE DATE:   /    !                                                      !   CO: 00.0 %    !                                  !
!                       !-------------------------------------------------------------------------!                                  !
! COMPLIANCE STATUS     ! FUEL CHARACTERISTICS              ! OPERATING RATES                                                       !
! UPDATE:      /  /     ! ********************              ! ***************                                                       !
!                       !                                   !   ANNUAL OPERATING RATE:          20 TONS SOLVENT USED                !
! EMERGENCY CONTROL     ! FUEL SULFUR CONTENT: 0.00 %       !                                                                       !
! ACTION PLAN           !                                   ! HOURLY MAXM DESIGN RATE:        .005 TONS SOLVENT USED                !
! ****************      !   FUEL ASH CONTENT: 00.0 %        !                                                                       !
! HAS BEEN SUBMITTED    !                                   !  BOILER DESIGN CAPACITY:                                              !
!                       !  FUEL HEAT CONTENT:               !-----------------------------------------------------------------------!
-------------------------------------------------------------------------------------------------------------------------------------
                                                                                              COMMENTS: SOLVENTS LOST              !
-------------------------------------------------------------------------------------------------------------------------------------
```

Figure 4-1. National Emissions Data System Point Source Listing.

needs of the photochemical modeler. One important deficiency, however, is the lack of hourly emission estimates. Provision for this additional temporal resolution is described in the subsequent section. Another shortfall is that the basic inventory will not disaggregate VOC and NO_x emissions into the classes needed by photochemical models. Techniques for accomplishing this are described in Chapter 7.0. The only other data required that may not be in the basic inventory are the various stack parameters needed in order to segregate elevated point sources from ground level sources. If the photochemical model requires vertical resolution of emissions, the point source records should include the following stack parameters to allow the modeler to calculate effective stack heights:

- Physical stack height
- Inside diameter of stack
- Exit gas temperature
- Exit gas velocity or volumetric flow rate

For point sources, information in the local agency files will often be more current than NEDS data, as errors may be corrected first in local files and only somewhat later in NEDS.

4.2 SPATIAL RESOLUTION

Photochemical models require that all emissions be associated with specific grid cells. Hence, prior to running a photochemical model, the emissions from each point source must be assigned to the grid cell in which the point is located. This assignment can be done manually using maps or automatically by computer.

Point sources can be manually assigned to grids by their UTM coordinates (or street addresses) on a map of the area which is overlaid with the inventory grid system (refer to Chapter 3.0). Map pins are sometimes convenient to mark source locations. It is advisable to check the street address against the UTM coordinates to identify possible errors in UTM assignments. Usually each grid cell is assigned a number according to some model-specific system, and this grid number and the source-type category should be entered into the data handling system for each point source.

An alternative to this manual process is to develop a computer program that automatically compares the UTM coordinates of each point source with the coordinates of each grid cell and assigns the point source emissions to an appropriate cell. For some photochemical models, preprocessor programs are available that may accomplish this function. The model documentation or developer should be consulted in order to determine whether this capability is available.

Generally, an automatic grid-coordinate-to-grid-cell approach is preferable because it is faster than manually locating all point sources on a map. This approach is especially attractive if (1) preprocessing programs for the purpose are available as part of the photochemical model, and (2) the grid assignment process may have to be repeated numerous times, as would be the case if the grid orientation or grid cell size would change. However, even if the grid assignment is computerized, it will usually be useful to provide grid system overlay over an accurate map of the area, in order to assist in visualizing and checking the assignments produced.

4.3 TEMPORAL RESOLUTION

One of the main differences between the detailed inventory used for photochemical modeling and the basic inventory is that the former should represent a typical weekday during the oxidant season.

Moreover, for that typical day, emission estimates must be made for each hour. In contrast, basic inventories used in rollback or EKMA contain annual or, in some cases, seasonally adjusted emissions. Three basic approaches can be used for determining hourly emissions from point sources for a given day: (1) plant or local agency contacts, (2) extrapolation from operating information contained in the basic point source record, and (3) engineering judgment.

Ideally, the most accurate means of determining hourly emissions would be to contact each plant in order to get operating records for each hour for a typical day during the oxidant season. Certain local agencies may also have this information. In practice, since this approach is quite resource-intensive, it is practical only for the largest emitters in the area. For example, power plants, which are large emitters of NO_x, generally keep detailed, hourly records of fuel firing rates and power output for each day of operation. Automotive assembly plants, refineries, and tank farms would be examples of other sources that could be contacted directly for operating information.

For many smaller point sources, reasonable temporal resolution can be obtained from the operating data that are typically coded on each basic point source record. For example, the NEDS listing shown in Figure 4-1 refers to an operation with annual emissions of 20 tons of VOC, with 40 percent of annual throughput occurring in the summer. This source normally operates 12 hours per day and seven days each week. Assuming uniform hourly emissions over a 13-week summer, the emissions rate is estimated to be (20 x 0.4)/(12 x 7 x 13) or 0.0073 tons per hour. Applying the conversion factor, 907 kg/ton, gives 6.7 kg/hr as the average emissions during summer operations. In the absence of more specific data, these emissions might be assigned to the period 0700 to 1900 each day.

For many sources, daily operation will be confined to one or two workshifts; thus, hourly operation during working hours would be determined by dividing the daily operating rate by 8 or 16. If hourly operating information is contained in local agency files, it may supersede the less detailed information from NEDS or EIS/P&R.

There are always some sources that are both too minor to warrant a plant contact, and for which no operating data will be coded into the basic point source record. In these cases, engineering judgment can often provide satisfactory estimates of hourly emissions. For example, many commercial establishments will operate all year, but only be open 8 to 10 hours a day and 5 to 6 days a week. Hence, as a good approximation, the annual operating rate in the basic point source record can be divided by 2,080 (i.e., 52 x 5 x 8) to estimate an hourly operating rate applicable during working hours.

Fixed-roof petroleum product storage tanks present a unique situation because breathing loss emissions are not a function of operation. Rather, test data[2] show that breathing loss emissions are simply a function of time of day. These tanks begin expelling vapors when heated by sunshine in the morning, and cease expelling vapors in the mid-afternoon when the heating process ceases. As an approximation, breathing loss emissions from fixed roof storage tanks can be assumed to occur uniformly from 8:00 a.m. to 3:00 p.m. Daily emissions from storage tanks can be estimated by procedures given in AP-42, Compilation of Air Pollutant Emission Factors.[3]

4.4 POINT SOURCE PROJECTIONS

As discussed in Chapter 2.0, emission projections must take into account growth as well as any regulations under consideration to control ozone precursor pollutants. The baseline projection considers the impact of expected growth in future years and the reduction in emissions that should occur as a result of existing control regulations. Control strategy projections, on the other hand, consider the reductions in emissions that would occur if alternative or additional regulatory programs were adopted. Control strategy projections may also take into account other-than-expected growth patterns which might result from the alternate control programs.

4.4.1 INDIVIDUAL FACILITY PROJECTIONS

The best approach for projecting emissions from major point sources is to obtain information on each facility. This type of information would ideally be determined by contacting plant management directly, or could be solicited on questionnaires. Generally, questionnaires would not be sent out solely to solicit projection information; however, this additional information may be solicited on questionnaires used to periodically update the baseline inventory. Permit applications submitted to various Federal, State, and local agencies should also be screened to get information on expected expansion or new construction. In addition, the local Metropolitan Planning Organization and other planning bodies should be contacted for any information they may have on projected industrial expansion as well as to comment on the reasonableness of any plans submitted by plant personnel.

Once this type of projected plant growth information is obtained, the agency needs to determine what regulations will apply, in order to estimate controlled emissions. In the baseline case, existing, applicable regulations would be imposed and evaluated. For instance, a fossil-fueled power plant now under construction and expected to start operation in 2 years would be subject to Federal new source performance standards for particulate, SO_2, and NO_x.

Hence, it would be reasonable to assume emission levels equal to the standards unless plant personnel indicate more stringent controls will be applied for some reason (e.g., to meet a more stringent local standard). Similarly, in control strategy projections, effects of any alternative standards would have to be evaluated.

When obtaining projection information from plant management, it is important to inquire whether any increased activity will occur at the existing facility or whether it will occur elsewhere, at another existing plant or at a new plant. If occurring at an existing facility, the agency also needs to determine whether the growth will be expansion to existing capacity or will require additional capacity. These considerations are important especially for major sources, since emissions must be assigned to a specific grid cell. They will also help the agency to determine what additional control measures are likely to be required. The schedule for completion of any expansion or new construction is also needed, in order to determine in what year the source must be included in the projection inventory.

As an example of making point source projections for specific sources, consider a facility employing a large open-top vapor degreasing operation that emitted 100 tons of solvent per year in 1977 (based on an annual production of 10,000 of a certain kind of metal part.) Assume that no control measures were taken to reduce solvent losses from the process. Now, suppose a plant contact was made and it was learned that 5 percent more metal parts would be produced per year until 1982 using the existing operation and that, in 1986, a replacement facility would be brought on line at another location that produced 20,000 parts per year. Moreover, suppose that the source is located in an ozone attainment area where RACT is not required on VOC sources. Then, in order to estimate VOC emissions from this source for a 1982 projection inventory, one could assume that since no additional controls would be expected, the current emission level could be multiplied by the ratio of cumulative growth in metal parts production (i.e., 5 years at 5 percent/year = $[1.05]^5 = 1.28$, or 128 percent) to estimate VOC emissions in 1982. In this manner, emissions in 1982 would be estimated at 128 percent of 100, or 128 tons per year, and the point source record for this projection year should be adjusted accordingly to take this growth into account.

Again, suppose a control strategy projection is desired for 1987 to evaluate the effect of RACT as an alternate control strategy. In this case, both growth and controls would have to be considered. As a first approximation, one could assume that since production is twice as much in 1987 as 1977, uncontrolled emissions from the replacement plant would be twice those of 1977, or 200 tons per year, assuming that a similar open-top vapor degreasing operation would be used in the new facility. Since the new plant would be subject to RACT in this control scenario, VOC emissions would be reduced by 45 to 60 percent from the uncontrolled case.[4] Hence, projected emissions in 1978 would be only 80 to 110 tons per year, depending on which RACT measures were instituted. Note that since a new facility was to be built between 1977 and 1987, a new point source form should be coded in the 1987 projection inventory and the old record deleted or assigned zero emissions.

As is obvious from this example, even when projection information is available for specific facilities, certain assumptions will have to be made in order to project emission levels for some future year. For instance, in the 1982 baseline projection, it was assumed that emissions would increase proportionately with production. This may not necessarily be entirely accurate, depending on the nature of the operation. This same assumption, along with an assumed emission reduction due to RACT, was also utilized in making the 1987 control strategy projection. This underscores the point made in Section 2.6 that projections are always somewhat speculative in nature.

4.4.2 AGGREGATE POINT SOURCE PROJECTIONS

In many instances, projection information will not be available for every facility in an area of interest. Some plant managements will not be willing or able to provide forecasts of their corporate plans, especially for more distant years. In addition, many plants in certain source categories (e.g., small industrial boilers) will be too small and too numerous to warrant the solicitation of projection information individually. In these situations, other procedures need to be employed to make projections of future emissions. Two possible approaches are discussed below.

In one case, projection information may be available on many point sources within a given category, but for various reasons is not obtainable for one or several facilities. For example, there may be 10 paint manufacturing plants in the area of interest, and successful contacts may have been made with only eight of these. In this situation, a reasonable approach to projecting growth and emissions at the remaining two plants would be to evaluate the growth trends in the plants for which projections are known and apply them to the plants for which no information was available. In the example of the paint manufacturing plants, if production was expected to expand by 6 percent per year, on average, for the eight plants, then this rate could be applied to the two plants to estimate expected growth. Then, knowing the increase in production, the appropriate control measures would be taken into consideration in making a baseline projection. In some cases, the emissions could be directly estimated by applying the average growth rate to a base year emission for each plant. Good engineering judgment is needed in this practice to screen out any unreasonable projections that may result.

For minor point sources, such as cold cleaning operations, where individual solicitation of projection information is unwarranted, the rate of growth of activity may be assumed equivalent to that of some growth indicator category for which projections have been made by local MPO's or by OBERS.[5] For example, it might be assumed that cold cleaning operations would grow at the same rate as industrial manufacturing in general. This rate can be readily estimated from projections of employment in industrial manufacturing categories.

Table 4-1 provides an example of local employment projections for a set of 10 employment categories or "sectors," of which one is "manufacturing." OBERS projections are provided in many more categories; some of the relevant OBERS categories are listed in Table 4-2. These projections were developed and are regularly updated by the U.S. Departments of Commerce and Agriculture and may be used, in the absence of local projections, as general indicators of growth.

Regardless of the indicators used for projections, the basic mechanics of projecting are the same: the ratio of the value of the surrogate indicator in the projection year to its value in the base year is multiplied by the aggregated activity level for the point source category in the base year. For example, if cold cleaning operations are assumed to correlate with the manufacturing sector in Table 4-1, then the level of this activity in 1985 would be 42/39, or 1.08 times that in 1980. In many cases the projection years of interest to the air pollution control agency will not directly correspond to the years for which growth projections have been made, thus requiring interpolation. Local input should be sought regarding whether straight-line or other interpolation methods should be employed.

Table 4-1. PROJECTED EMPLOYMENT BY SECTOR IN HILLSBOROUGH COUNTY[a]
(in thousands)

Employment Sector	1980	1985	1990	1995	2000
Agriculture	7	7	8	8	9
Mining	2	2	2	2	2
Construction	19	21	22	24	25
Manufacturing	39	42	45	48	51
Transportation, communications, and public utilities	21	23	25	27	28
Wholesale and retail trade	72	79	85	90	95
Finance, insurance and real estate	16	18	19	20	21
Services, miscellaneous, and mining	47	51	55	58	61
Government	43	47	50	53	56
Other	28	31	33	35	37
TOTAL	293	321	344	365	385

[a] Refer to Reference 5

Table 4-2. SELECTED OBERS INDUSTRIAL CATEGORIES[5]

Chemicals and allied products

Food and kindred products

Primary metals

Petroleum refining

Lumber products and furniture

Paper and allied products

Fabricated metals and ordnance

Textile mill products

Other manufacturing

Total manufacturing

When aggregate growth is determined for a source category in the above manner, a major problem arises in attempting to distribute the increased activity appropriately to the grid cell level. In other words, difficult assumptions must be made regarding the probable location of the new activity. One way to apportion growth is to assume that it occurs only at existing plants in the same source category. For instance, if the 10 paint manufacturing plants in the previous example manufactured 10 million gallons of paint in 1977, and 15 million gallons were projected in 1982, then the additional 5 million gallons could be assumed to be manufactured at these same plants. The amount of production assigned to each plant would be in proportion to the quantity currently manufactured there.

If the agency feels it is not reasonable to assume that all growth within a particular source category will occur at existing facilities, an alternative is to apportion the growth according to the fraction of increase of industrially zoned land within each grid. Using the above example again, if 5 percent of the projected areawide increase in industrially zoned land occurred within a given grid cell, then 250,000 gallons per year (or 5 percent of 5 million gallons) of additional paint production would be assigned to that cell. In this approach, since the growth is not assigned to existing facilities, new point source records may have to be coded. Again, the applicable control regulations would have to be evaluated in order to determine the resulting emissions.

4.4.3 POINT-SOURCE PROJECTION REVIEW AND DOCUMENTATION

Because the projection inventories are so important in control strategy development, they should be reviewed internally by the air pollution control agency and presented to as many other groups as possible for comment before being finalized. In order for the projection inventories to undergo this careful scrutiny, it is essential that all assumptions, procedures, and data sources be carefully documented. This review and documentation process will help assure that the projections are (1) consistent with other projections being made by various groups in the area, (2) objective in the sense that they are not biased in order to promote a particular policy, (3) open, because all assumptions, etc., are clearly stated for public review, and (4) defensible, because of all the above characteristics.

The key aspects of point-source projections that will invite criticism are: (1) which indicators are used for projecting activity level growth; (2) when and where this growth will occur, and concomitantly, whether it will be accommodated by expansion of existing facilities or new construction; and (3) what emissions will be associated with this growth, either in the baseline case or as a result of various candidate control strategies. When planning, compiling, and reviewing the point source projection inventory, the agency should focus particular attention on these issues.

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5.0 HIGHWAY VEHICLES

5.1 INTRODUCTION

Highway vehicles are frequently the largest single source of both VOC and NOx emissions in an urban area; hence, it is essential for the photochemical modeling effort to have an accurate inventory of highway vehicle emissions. Typically, the annual, countywide emission inventory of highway vehicle emissions is determined by some technique (e.g., countywide gasoline sales) that yields only gross emission estimates for the area. This type of inventory is not a good starting point for the detailed photochemical modeling inventory for several reasons. First, such an inventory is not spatially or temporally resolved to the degree needed by photochemical models. Second, many highway vehicle control strategies cannot readily be evaluated using this type of inventory. Third, and most important, transportation planning data that can often be utilized to compile detailed base year and projection inventories are available in most urban areas (>50,000 population). Hence, during the planning stages of the inventory effort, the air pollution control agency should contact the local MPO and proceed with the development of the detailed photochemical modeling inventory based on detailed transportation planning data.

5.2 NATURE OF AUTOMOTIVE EMISSIONS

Because the various models available for compiling detailed highway vehicle inventories treat the exhaust and evaporative components of automotive emissions differently, it is important that the reader have a basic understanding of the nature of automotive emissions prior to selecting a particular approach. The three major components of automotive emissions are briefly discussed below.

Travel related emissions - Travel related emissions are also referred to as exhaust emissions, or hot stable operating mode emissions. These emissions are a function of VMT and occur during travel when the vehicle is warmed up past the cold start (or hot transient) mode.

Trip-end related emissions - These consist of startup and hot soak emissions. Startup emissions are those exhaust emissions that occur near the origin of the trip when the vehicle is warming up. Startup emissions include both cold start and hot transient emissions and are a function of ambient temperature, the number of trips, and the number of vehicles started by engine operating temperature mode. Cold start emissions are those that occur roughly within the first 505 seconds of a start after the engine has been turned off for four hours or more, in the case of noncatalyst-equipped vehicles, and for one hour or more for catalyst-equipped vehicles. Hot transient emissions are those that occur roughly within the first 505 seconds of a start after the engine has been turned off for less than one hour. Hot transient emissions are only associated with catalyst-equipped cars, and are considerably less than cold start emissions. Hot soak emissions are evaporative losses that occur from the carburetor after the engine has been shut down. These emissions occur at the end of a trip, primarily within the first hour after engine off.

Vehicle Related Emissions - Also known as diurnal emissions, these are evaporative emissions from the fuel tank, caused by diurnal changes in ambient temperature. An increase in temperature results in the expansion of the air-fuel mixture in a partially filled fuel tank, and as a result, gasoline vapor is expelled into the air. These emissions are a function of the number of vehicles.

5.3 OVERVIEW OF HIGHWAY VEHICLE INVENTORY PROCEDURES

The basic process for compiling the detailed highway vehicle emission inventory necessary for photochemical modeling is shown in Figure 5-1. Four distinct tasks are involved, viz., development of the required transportation input, use of an emission factor model, use of a network emission model, and conversion of line source emissions to total grid emissions.

Two fundamentally differing approaches can be used for carrying out the general methodology outlined in Figure 5-1; (1) a link-based approach and (2) a "hybrid" approach.[1] In the link-based approach, all three types of automotive emissions are calculated for each link in the highway network based on VMT on that link. A single emission factor is developed for each link in terms of g/VMT, representing total automotive emissions. Trip-end and vehicle related emissions are included in this single emission factor and are assumed to be "smeared out" evenly over the entire link.

With the link-based approach the procedure works basically as follows. The core of the analysis is the network emission model. This model takes each traffic link, multiplies the link length by the traffic volume to determine VMT for the link, and multiplies the VMT by an emission factor. This procedure yields emissions for each link and these link emissions are then summed using various methods during the conversion to gridded emissions function.

In the hybrid approach, separate estimates are made of travel, trip-end, and vehicle related emissions, and assigned to those zones in which they actually occur. The hybrid approach is conceptually more accurate than the link-based approach, and allows certain control strategies to be simulated more easily. However, this approach is generally more data intensive.

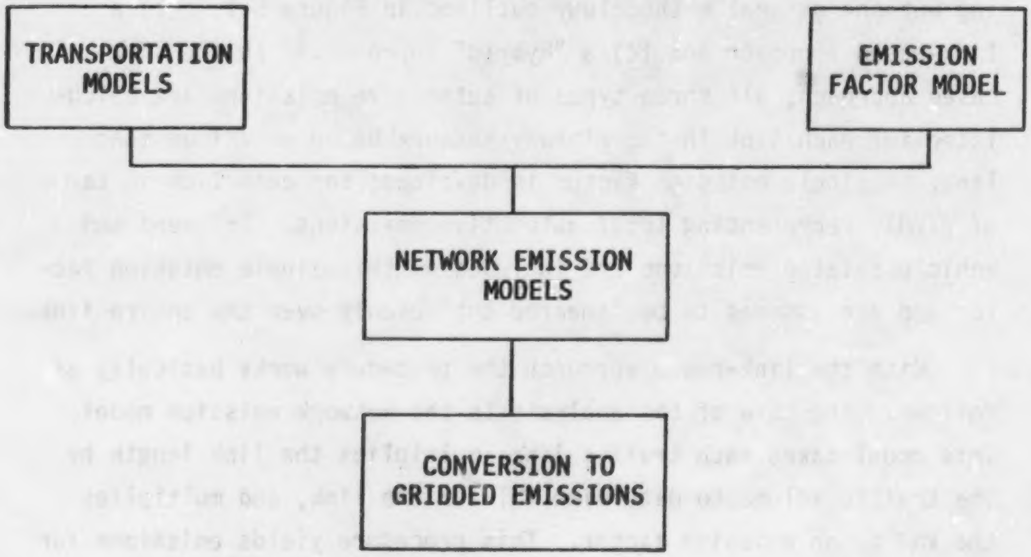
TRANSPORTATION MODELS
EMISSION FACTOR MODEL
NETWORK EMISSION MODELS
CONVERSION TO GRIDDED EMISSIONS

Figure 5-1. Overview of Processes for Compiling Detailed Highway Emission Inventories

Because the hybrid approach is so much more data intensive, and because, at this time, no generally available models using the hybrid approach have been developed, the emphasis in Volume II will be on the link-based approach. Some discussion of the hybrid approach will be included, however, for those agencies that wish to incorporate this added level of detail to their highway vehicle emission inventory.

The choice of whether to use the link-based or hybrid approach must be made before the highway vehicle emission inventory is begun. This choice affects the types of data that must be collected as well as the calculation procedures.

5.4 TRANSPORTATION PLANNING DATA

As shown in Figure 5-1, the starting point for the detailed highway vehicle inventory is the transportation planning process. All urban areas with populations greater than 50,000 are required by Federal law to have continuous, comprehensive and cooperative (3-C) transportation planning processes to enable local governments to better plan their major street systems. Generally, metropolitan planning organizations (MPO's) are the designated agencies to do transportation planning.

As part of the transportation planning process, batteries of computer programs (i.e., transportation models) are utilized to estimate traffic flow on transportation networks for current and projection years. In most urban areas, either FHWA's PLANPAC/BACKPAC battery[2] or UMTA's UTPS battery[3] is used for this purpose. A few states use different program batteries but these are usually quite similar to the FHWA or UMTA systems.

The basic input to transportation models consists of current and projected population and economic data (disaggregated to the traffic zone level) as well as descriptions of the current and projected traffic networks in the area of concern. The primary output from transportation models that is of concern to the air pollution agency is the historical record. This file contains link-by-link information on traffic volumes as well as various other link-related data needed to calculate emissions at the link level. Table 5-1 indicates the type of data that can be associated with each link in the PLANPAC/BACKPAC series. Each link is spatially defined by an a-node and b-node and x and y coordinates. The associated information constitutes the historical record. It should be noted that not all data items are gathered for each transportation study; the basic battery of programs can operate with only columns 2-21 specified.

With the link-based approach, the desired product from the transportation model is link-by-link traffic volume, by hour, for both the base year period and the future or target year period. With the hybrid approach additional data requirements are data on trip origin and destination, by purpose, by hour. These data are potentially available from the transportation modeling process but several limiting factors should be considered.

First, the transportation modeling process used today is fundamentally similar to the process that began 20 to 30 years ago. While this modeling process is effective for transportation purposes, it was not originally intended for use in air quality work. Several assumptions and procedures are included that have little effect on transportation planning but do affect air quality planning. The most significant of these is the "total VMT" concept used in air quality work. Total VMT is seldom used in transportation modeling and is therefore difficult to derive. Total travel

Table 5-1. LINK DATA FOR PLANPAC/BACKPAC URBAN TRANSPORTATION PLANNING BATTERY

Columns	Contents	
1	Unused (perhaps identification)	
2-6	a-node number	
7	a-node leg number (0-3)	
8-12	b-node number	
13	b-node leg number (0-3)	
14-17	Distance (XX.XX)	
18	T or S for time or speed (a-b)	a-b (Note 1)
19-21	Time or speed (a-b) (X.XX/XX.X)	
22-24	Turn penalty codes at node b	
25-28	Hourly capacity (a-b)	
29-31	Conversion factor (VPH/ADT)	
32-36	Directional count (a-b)	
37-38	Street width (a-b)	
39	Parking (a-b)	
40	Unused (a-b)	
41	T or S for time or speed (b-a)	b-a (Note 2)
42-44	Time or speed (b-a) (X.XX/XX.X)	
45-47	Turn penalty codes at node a	
48-51	Hourly capacity (b-a)	
52-54	Conversion factor (VPH/ADT)	
55-59	Directional count (b-a)	
60-61	Street width (b-a)	
62	Parking (b-a)	
63	Unused (b-a)	
64	Administrative classification	
65	Functional classification	
66	Type facility	
67	Surface type	
68	Type area	
69-70	Predominant land use	
71-74	Link location	
75-78	Route number	
79	Condition	
80	Unused	

Notes:

1. If an "X" is coded in Column 41, the a-b values in Columns 18-40 are halved and moved to Columns 41-63 of the card.

2. If only an "all or nothing" assignment is desired, only Columns 1-21 need to be coded.

Source: Computer Programs for Urban Transportation Planning, PLANPAC/BACKPAC General Information Manual, U.S. Department of Transportation, Federal Highway Administration, Washington, D.C., April 1977.

in the transportation planning process consists of VMT on: (1) links; (2) centroid links, representing interzonal travel on uncoded streets; and (3) intrazonal travel, representing short trips within the traffic zone of origin that are not assigned to links because they do not enter another traffic zone. All three categories must be included to properly characterize total VMT. To include intrazonal travel with the PLANPAC/BACKPAC system, the TRPTAB program must be run, which generates the number of zone-to-zone traffic interchanges. With the UTPS system, program UMFTR is used to obtain the number of intrazonal trips. The number of intrazonal trips for each zone is indicated by interchanges with itself, i.e., zone 1 to zone 1, 2 to 2, 3 to 3, etc. Once the total number of intrazonal trips is known, it is necessary to develop an average intrazonal trip distance for each zone to develop a VMT figure. The centroid connector length can be used if properly located. The use of this information in calculating emissions from intrazonal VMT is discussed in Section 5.6 on network emission models.

A second limitation deals with the accuracy of the data input to the transportation modeling process. The accuracy of traffic volumes is no better than the population, employment, and network data used to project these volumes. If the transportation modeling process is several years old, the projections of population, employment, and new roads or transit systems (network description) may no longer be accurate. This will cause errors in the projected traffic volumes. The air pollution agency should work very closely with local land use and transportation planners to obtain accurate projections, and the projections should be reviewed by qualified personnel before the traffic volumes are used for air quality work. If they are found to be significantly inaccurate, it may be necessary to update the transportation study. This is an extremely costly procedure and may involve several months of effort by land use and transportation planners.

A third limitation involves the availability of traffic assignments for the desired years of analysis. Unless short-term traffic projects have been made for transportation system management work or specifically for air quality planning work, traffic assignments will not be available for 1982 or 1987. A base year period and a target year period, such as 1995 or 2000, are the projections most likely to be available.

Two methods to obtain link volumes for interim periods without a major transportation study update are available, although neither results in a high degree of accuracy. The first method uses manual calculations based on land use trip generation rates, an estimate of through travel, and professional judgement. This method should only be used by an experienced traffic analyst and as a last resort. The second method relies on linear interpolation of traffic assignment from two known periods. The future year traffic assignment assumes that all projected land use growth has occurred and that all projected transportation improvements have been built. Actually, in interim periods, this is rarely the case. Land use growth does not usually occur evenly across the city at a steady rate; rather, it more often occurs in spurts in specific areas. Similarly, the traffic diversion resulting from construction of a major transportation facility is often extremely difficult to calculate. Thus, in high growth areas, this latter method is especially difficult to use. Hence, because of the large effort involved in photochemical modeling, it is recommended that special traffic assignments be prepared unless the existing assignments are within a very few years of the projection years being used in the photochemical modeling effort.

Another limitation stems from the inherent lack of temporal resolution in the transportation planning data. First, since the underlying travel survey information used in the modeling process is only available for weekdays, the resulting link and trip generation data will only apply to weekday conditions. Hence, without extensive modifications, transportation planning data cannot be utilized to develop inventories representative of weekend conditions. Second, traffic volume data in the historical record generally represent average daily traffic (ADT) or peak hourly traffic. Hence, traffic count data must generally be obtained to generate the diurnal traffic volume information required in the detailed highway vehicle inventory, or else such data must be borrowed from another urban area. (Temporal resolution is discussed in more detail in Section 5.6.) Third, transportation planning data may not reflect any strong seasonal component that may exist in a given area. The local transportation planning agency should be consulted to determine if the transportation data are representative of the oxidant season and if not, what adjustments can be made.

Another limitation is that many of the data items required to accurately develop highway vehicle emission factors are not readily available from transportation planning data. EPA's MOBILE1, for example, applies corrections based on vehicle speed, cold/hot operating mode, vehicle mix and age, temperature, humidity, load, trailer towing, and air conditioning. With the exception of speed and cold/hot operating mode, little information on the other correction parameters is available from the transportation planning process. The specification of those correction parameters from transportation data is discussed in the next section.

Finally, differences may exist between the areas covered by the photochemical modeling grid and the transportation planning boundary. In most cases, the air quality analysis area is likely to be larger than the area used for transportation modeling. Where this is the case, no traffic volumes will be available from the transportation study for the outer areas. Fortunately, however, because these outer areas are likely to be rural and to have very little VMT, they probably contribute little to the overall highway emission total. The best way to include them is to have transportation modelers code the outer area streets into the transportation network and to add the new links to the historical record. The new links cannot be used in the normal traffic assignment process but traffic volumes can be manually added. Existing volumes can be obtained from traffic counts, or if these are not available, can be estimated by a transportation planner. For future year periods, existing volumes can be factored. In rural areas, an annual growth factor of 1 to 3 percent is probably appropriate unless significant growth is expected during the forecast period. Local transportation planners should verify the factor used. In special cases where major freeways run through the outer area, carrying significant traffic volumes, traffic counts will likely be available from the State Highway Department or the State Department of Transportation. For future years, projected traffic volumes can be obtained by using the growth factor of each freeway when in the transportation area; where this would be inaccurate because of adjacent growth, the State can usually provide an estimate based on historical growth from traffic counts or from a statewide model.

5.5 EMISSION FACTOR MODELS

As shown in Figure 5-1, the emission factor model is a necessary component in the detailed photochemical modeling inventory process. Emission factors are multiplied by VMT in the case of link-based models, as well as trip ends and number of vehicles in hybrid models, to estimate highway vehicle emissions. Two EPA highway vehicle emission factor models are currently available for use: (1) MOBILE1 and (2) Modal Model. The latter is not generally recommended for use in conjunction with the detailed photochemical modeling inventory; however, it is discussed briefly for those agencies that desire the added accuracy that may result in certain instances.

5.5.1 MOBILE1

In almost all cases, MOBILE1 is the most appropriate emission factor model. While available as a separate program, MOBILE1 is also built into several available network emission calculation models such as HWYEMIS1 and APRAC-II. (These network models are discussed in the next section.) The basis and use of MOBILE1 are documented in detail in Reference 4 and 5. The following inputs are needed to run MOBILE1:

- Speed
- Percent VMT of non-catalyst-equipped LDV, accumulated in cold start mode
- Percent VMT of catalyst-equipped LDV, accumulated in cold start mode
- Percent VMT of catalyst-equipped LDV, accumulated in hot transient mode
- Ambient Temperature
- Vehicle Mix
- Mileage accrual by vehicle age
- Air conditioners in use
- Fraction of vehicles with an additional 500-lb loading
- Percent trailer towing
- Absolute humidity
- Additional heavy duty vehicle (HDV) correction factors

Given these user supplied inputs, MOBILE1 computes composite emission factors for three regions:

- Low Altitude Regions
- California
- High Altitude Regions (>4,000 feet)

The six vehicle types for which composite emission factors are calculated are:

- Light-Duty Vehicles (LDV)
- Light-Duty Gasoline-Powered Trucks, 0-6,000 lbs GVW (LDT1)
- Light-Duty Gasoline-Powered Trucks, 6,000-8,500 lbs GVW (LDT2)
- Heavy-Duty Gasoline-Powered Trucks (HDG)
- Heavy-Duty Diesel-Powered Vehicles (HDD)
- Motorcycles (MC)

The three pollutants for which MOBILE1 computes composite emission factors are:

- Hydrocarbons (HC)
- Carbon Monoxide (CO)
- Oxides of Nitrogen (NO_x)

MOBILE1 calculates composite emission factors for calendar years 1970 through 1999. These factors account for current deterioration rates as well as anticipated emission reductions due to the Federal Motor Vehicle Control Program.

Several options are allowed in MOBILE1 to make it more flexible. For instance, MOBILE1 includes options to allow for various rates of emission control device deterioration in addition to those assumed in the base case factors. Different timetables for the implementation of new vehicle emission standards can be reflected.

MOBILE1 allows the user to optionally apply inspection/maintenance (I/M) credits to emissions estimates, taking into account these factors. Emission reduction credit attributable to an annual I/M program will vary according to the type of program in effect, depending on (1) the stringency factor for determining the emission level for passing or failing tested vehicles; (2) the calendar year of interest and calendar year when I/M was first implemented; (3) the presence of an adequate program of mechanic training; and (4) subsequent years of I/M program operation.

MOBILE1 optionally outputs composite crankcase and evaporative HC emission factors for each vehicle type, in addition to the total HC emission factor (which includes the exhaust HC emissions). It is important in the detailed photochemical modeling inventory to maintain the distinction between exhaust and evaporative emissions as the species composition of each of these emission components is significantly different. MOBILE1 also has an option which allows the user to generate either total or non-methane hydrocarbon composite emission factors. The choice here in the photochemical modeling inventory will depend on whether the "split factors" available for apportioning VOC into classes have been adjusted to apply to nonmethane or total VOC emissions. (This is discussed further in Chapter 7.)

The most difficult part of using MOBILE1 in the compilation of the detailed highway vehicle inventory is the specification of appropriate values for the user inputs. The more important input variables to specify accurately are speed, cold/hot start operating percentages and temperature. Table 5-2 demonstrates the sensitivity of MOBILE 1 composite emission factors to changes in certain input variables. Similar investigations regarding the importance of cold start percentages indicate that this variable is as important as the speed variable in affecting emission rates. The approaches described in the following sections are recommended for specifying values for the MOBILE1 input variables.

Table 5-2. EFFECT OF SOME MOBILE1 VARIABLES ON 1978 EMISSION FACTORS

Variable	Variable Change Tested		Percent Change in Composite Emission Factors[3]	
	Value A	Value B	NMHC[1]	NO_x
Speed, mph	15	55	-64	45
Temperature	30°F	80°F	-22	-27
Relative humidity	60%	80%	NA[4]	-10
Barometric pressure	29.5 in. of Hg	30.5 in. of Hg	NA	1
% LDV's using A/C	0%	48%	3	4
% LDV's towing trailers	0%	1%	0[5]	0
% LDV's with excess load	0%	15%	1	0
% LDT1's with excess load	0%	40%	0	0
% LDT2's with excess load	0%	75%	0	0
Heavy-duty truck load[2]	All Empty	All loaded	5	9
Heavy-duty truck engine	All Small	All large	6	1
Travel weight by vehicle age	MOBILE1 default	10% shift to newer vehicles	-9	-2

Notes:

1. NMHC excludes crankcase blow-by.
2. Heavy-duty truck characteristics are extremes of range allowed by MOBILE1.
3. Percent change = 100* (EF(B) - EF(A))/EF(A).
4. NA = not applicable
5. Percent change of zero indicates change less than 0.5%

Source: Reference 1

5.5.1.1 Speed

Two sets of vehicle speeds are commonly included for each link in the historical record. They are referred to most often as input speeds and output speeds. Input speeds are the speeds coded directly into the link description (see Table 5-1, columns 19-21, 42-44). These are often posted speed limits and do not necessarily reflect actual driving speed. In other cases, the coded speed may be based on field surveys of actual driving time. Field surveys, when complete, reflect current driving speeds. They do not, however, reflect future year driving speeds because of the effect of increased traffic volumes on driving speed.

Output speeds are those speeds resulting from a capacity restraint traffic assignment or manual adjustment. The capacity restraint program compares vehicular capacity of a link to assigned volumes. Depending on the volume to capacity ratio, the speed is lowered proportionately on the overloaded link to discourage its use as a trip path between certain zonal pairs. With this process, output speeds are always lower than input speeds if there is any congestion in the network. They may, in fact, be too low on certain links and may show illogical route continuity. This is because the speed factor is actually an impedance factor that is mechanically manipulated and does not necessarily correspond to reality. On certain links, after continued application of the capacity restraint process, speeds are often below 5 mph with no apparent justification. In other cases, speeds on individual links are manually adjusted by traffic analysts during the network calibration process. Again, these adjustments are made to mechanically change the link impedance, and speeds may not correspond to driving conditions. For these reasons and contrary to frequent practice, neither the input nor the output speeds should be used as input to MOBILE1.

The best available method for determining speeds at this level of analysis is to use program SPEED. This program will soon be added to the BACKPAC battery.* The purpose of SPEED is to estimate individual link speeds from link characteristics (facility type, area type), degree of congestion (volume/practical capacity relationship), and volume capacity versus speed curves (user supplied or program specified). SPEED reads, updates, and copies the traditional historical record file with the insertion of an additional link speed. The link speed can later be used by either of the recommended network emission models. A similar program is available with the UTPS system within UROAD.

Even after using SPEED or a similar program, the calculated speeds may differ by as much as 25 percent or more from actual speeds because of the difficulty in quantifying the volume/capacity/speed relationship and the difficulty of calculating capacity. Still, these speeds are the best available and, on a regionwide basis, probably cause no errors of an unacceptable magnitude.

5.5.1.2 Cold/Hot Mode Vehicle Operation

MOBILE1 requires that the user define the three cold/hot start percentages shown below:

Percent of non-catalyst-equipped LDV VMT accumulated in cold start mode (PCCO).

Percent of catalyst-equipped LDV VMT accumulated in cold start mode (PCCC).

Percent of catalyst-equipped LDV VMT accumulated in hot start mode (PCHS).

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*Program SPEED is available from: Chief, Urban Division, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C. 20590.

Several options are available to develop these percentages. The simplest course is to assume single, fixed percentages for all speeds, locations, times, etc. Alternately, if the link-based network emission models HWYEMIS1 or APRAC-2 (these are described in the next section) are used, a subroutine automatically calculates these percentages based on assumed values (Table 5-3) expressed as a function of locale and time during the day. Area types and land use classifications coded into the historical record are combined into the locales shown in Table 5-3. Unfortunately, not all cities will have coded these fields on the historical record, or if they have been coded, they may not correspond to those accepted by HWYEMIS1 and APRAC-2. If the area and land use type by link are not in the historical record or do not correspond to those accepted by the models, the only way to derive them is through a cumbersome manual procedure whereby the proper classification is added to each record in the historical record. This latter alternative will be resource intensive and should be carefully evaluated prior to implementation.

Locale-specific cold/hot start percentages can be derived using a procedure developed for FHWA.[7] A detailed description of this procedure is too lengthy to include here. Basically, origin/destination survey data, or other suitable transportation planning sources, are used to determine the cold and hot start fractions as well as the fraction of travel represented, both by trip purpose and by hour. Then, using trip distribution data with terminal times included, the transient mode by purpose is determined. Finally, the contributions of each trip purpose to the cold/hot mode fractions are calculated for both catalyst and non-catalyst equipped cars. Theoretically, cold/hot percentages can be calcu-

Table 5-3. ASSUMED PERCENTAGES OF COLD AND HOT TRANSIENT VEHICLE OPERATION IN APRAC-2 AND HWYEMIS1

Time Interval Local Time	Locale		
	Downtown (%)	Suburban Commercial (%)	Residential and Other (%)
1800 - 0700	5 C 10 HT	0 C 10 HT	50 C 0 HT
0700 - 0900	0 C 0 HT	0 C 0 HT	80 C 0 HT
1000 - 1600	0 C 30 HT	0 C 10 HT	10 C 70 HT
1600 - 1800	60 C 20 HT	0 C 0 HT	10 C 10 HT

Source: Reference 6

lated for each zone and each hour by this procedure. In practice, however, it is recommended that percentages be calculated for zonal aggregates and for longer time intervals to minimize the amount of work involved. The resulting values can be substituted for the percentages incorporated in HWYEMIS1 and APRAC-2.

5.5.1.3 Ambient Temperature

When MOBILE1 is run, an ambient temperature must be input for each composite emission factor calculated. When HWYEMIS1 is used, incorporating MOBILE1, a single temperature is input for the period of interest. When APRAC-2 is employed, hourly meteorological data are input that include ambient temperature. In either case, appropriate temperatures should be chosen that are representative of conditions on the typical day being modeled.

5.5.1.4 Vehicle Mix

Vehicle mix refers to the fraction of each type of highway vehicle in the entire vehicle fleet. A default option exists to the user of MOBILE1 to use the following fractions for the six vehicle types (see Section 5.5.1) if locale-specific data are not available: 0.803, 0.058, 0.058, 0.045, 0.031, and 0.005.

Data on vehicle type are available from two sources in the transportation study process. The first source of data is the ongoing traffic count program. Vehicle classification counts are usually taken at a few locations each year. These data are sometimes of limited benefit for at least three reasons:

1. An adequate breakdown of truck types is not usually available from these counts.
2. The percentage of vehicle types on a street at a given location does not indicate the relative fraction of total VMT contributed by that vehicle type, unless the overly

simplified assumption is made that all vehicle types travel the same distance each day.

3. Counts are highly variable by location; no adequate measure is available to determine what the areawide fractions should be.

A second source of vehicle mix data is available from transporation studies. In larger cities, truck surveys were made as part of the original inventory phase. In these cities, a truck trip table is developed (sometimes taxis are added) for the base year in much the same manner as the purpose trip tables. It is added to the purpose trip tables when the purpose trip tables are merged after trip distribution. The truck trip table can be assigned separately before the trip tables are merged. The assignment process is done with the standard assignment programs, i.e., LOADVN with the PLANPAC/BACKPAC series and UROAD with the UTPS system. When the truck assignment is compared to an assignment with all trip purposes, the percentage of trucks by subarea is readily apparent. This process is of sufficient difficulty to make it inadvisable to pursue in most cases. Even after the process, the percentage of trucks must still be broken down into the four MOBILE1 truck categories.

The third and most usable approach is to obtain data on vehicle registration from the state. These data are usually available on a county level and can be manipulated into the six vehicle type categories. Again, the assumption required is that all vehicle types travel the same distance each day.

5.5.1.5 Mileage Accrual By Vehicle Age

MOBILE1 takes into account vehicle age and mileage accumulated by each model year when calculating composite emission factors. A set of default values are built into MOBILE1 for the six vehicle types described previously and for model years 1970-1999. Alternately, the user can supply vehicle registration data or mileage accrual by vehicle age, in which case MOBILE1 uses this information to calculate emission factors. Generally, many states will have registration data for use in MOBILE1 but fewer have data on mileage accrual by vehicle age.

5.5.1.6 Air Conditioning, Heavy Load, Trailer Towing

Sensitivity studies summarized in Table 5-2 indicate these values affect emission rates very little. Local data on these factors are almost never available; however, since the impact is small, reasonable values can be estimated for the summer season without incurring significant error.

5.5.1.7 Absolute Humidity

Humidity is important in determining the NOx emission rate. The MOBILE1 default value is 75 grains per pound of dry air. Since NO_x is sensitive to humidity, local meteorological records should be consulted to obtain a more accurate figure for the summer season.

5.5.1.8 Additional HDV Correction Factors

Parameters for additional HDV correction factors are:

- Average gross vehicle weight (GVW) for heavy-duty gasoline (HDG) vehicles
- Average GVW for heavy-duty diesel (HDD) vehicles
- Average cubic inch displacement for HDG vehicles
- Average cubic inch displacement for HDD vehicles

These parameters have little effect on emission factors and data on them are almost impossible to obtain. Default values are recommended.

5.5.2 MODAL MODEL

Evidence suggests that EPA's Modal Model may, in certain instances, yield more accurate estimates of highway vehicle emissions than MOBILE1.[8] However, the usefulness of the Modal Model for a regional analysis is limited for several reasons. First, it is designed to estimate only light duty vehicle (LDV) exhaust emissions. The planner must compute truck emissions and evaporative emissions by other means. Second, the model accurately predicts the emissions of LDV's operating in a stabilized mode, but not of those in a startup mode. Third, emissions for calendar years after 1977 are not yet available. Finally, and most importantly, the model requires vehicle speed profile data at one-second intervals. Such detailed speed information aids in developing a more accurate emission factor, since it accounts for acceleration, deceleration, idling, and free-flow operations. Such detailed speed information, however, is rarely available even for a particular link, much less for all links within an urban region or subarea. To employ this model in practice requires that each link be characterized by one or more speed curves. The difficulty in assigning speed curves to each link, together with the above- mentionedlimitations, generally precludes the use of this model in compiling photochemical modeling inventories.

5.5.3 COMPUTING SO_2 AND PARTICULATE EMISSIONS

Neither MOBILE1 nor the Modal Model calculates emission factors for SO_2 or particulate. Average emission factors for these pollutants, available from Supplement 5 of AP-42[9], can be used to complete the highway vehicle emission inventory.

5.6 NETWORK EMISSION MODELS

The hub of the highway vehicle emission calculation process is the network emission model. As shown in Figure 5-1, the network emission model combines the transportation data and emission factors to compute highway vehicle emissions at the link level.

As mentioned in Section 5.3, two types of network models can be employed for developing highway vehicle emission estimates: (1) link based and (2) hybrid models. The use of each of these two types of network model is discussed below. Emphasis is placed on link based models as no standard hybrid models are currently available for general use.

5.6.1 LINK BASED NETWORK EMISSIONS MODELS

The two network emission models recommended for use are HWYEMIS1[10] and APRAC-2.[6] With the HWYEMIS1 program, link speeds and link data are taken from the historical record and, with MOBILE1 input parameters, emission factors are produced on a link-by-link basis. The program produces a file to interface with SAPLSM, an FHWA program that sums link emissions by grid cell. The file can also be interfaced with other emission gridding programs, as discussed in the next section.

APRAC-2 was originally written containing the AP-42 Supplement 5 mobile source emission factors; the program has recently been modified to include MOBILE1 emission factors. This model has two major components: (1) an emission module called EMOD and (2) a diffusion module call DIFMOD. Only the EMOD module is of use in this context. The EMOD module works much the same as HWYEMIS1, i.e., historical record data and MOBILE1 data are combined to produce link-by-link emission factors. Link emissions are summarized by user-specified grids for as many as 625 grid cells.

Of the two network emission models recommended, HWYEMIS1 is less data intensive than APRAC-2, is easier to use, and interfaces easily with other DOT programs. At the same time, it has certain disadvantages when compared to APRAC-2. These disadvantages are chiefly related to its handling of traffic data and cold start percentages. APRAC-2 excels in these two areas because of (1) the ability to vary traffic by hour, by locale, by direction; (2) because cold start percentages can be input directly and a new set of emission factors are created for each hour; and (3) because the ability to change traffic and emission factors (including the temperature) by hour allows a more realistic simulation of actual conditions over a multihour period.

SAPOLLUT[11] is another program that has been used as a network emission model. HWYEMIS1 is an update of this model incorporating MOBILE1 rather than the obsolete Supplement 5 emission factors. Although HWYEMIS1 has lost some of the flexibility of SAPOLLUT, on balance, it is more desirable to use HWYEMIS1 than obtain the SAPOLLUT program and insert MOBILE1 or otherwise modify the program. Specific details on HWYEMIS1 and APRAC-2 are given in the following section.

5.6.1.1 HWYEMIS1

Programs and documentation for HWYEMIS1 are available from:

U.S. Department of Transportation
Federal Highway Administration (HHP-23)
Urban Planning Division
Washington, DC 20590

It can be run with either the PLANPAC/BACKPAC or UTPS program batteries. The necessary input data to HWYEMIS1 are:

- Historical record data containing:
    - network description
    - speed by link
    - traffic volume by link
    - area type
    - land use type
    - facility type
- Time interval of the analysis
- Percentage of ADT occuring during time interval of analysis
- MOBILE1 inputs

The network description coded on the historical record is described in Section 5.4 on transportation planning data.

HWYEMIS1 reads ADT (i.e., 24-hour traffic volume) from the historical record and factors it into four time intervals: 1800-0700, 0700-0900, 0900-1600, and 1600-1800. These time intervals are used in connection with the cold start percentages (see Table 5-3). Optionally, these can be manipulated in combination with the percentage of ADT to produce any time period.

Temporal factors for distributing ADT from this historical record into hourly or other time increments can be derived from several sources. Generally, local traffic count data yield the most acceptable traffic distributions. To use this kind of data, counts from across the area must be combined in some manner to represent an average hourly distribution for the entire analysis area, a specific link type, or a subarea, depending on model requirements. Various methods are available. The method to be used depends on the variations in distributions and whether the data are on a computer in an accessible form. If computer access is available, the most accurate method is to develop a weighted average distribution based on all counts in a given category. For example, all adjusted north-bound CBD expressway links can be stratified and a weighted average developed. In other cases where this capability is not available, manual techniques can be used. One technique is to draw north-south and east-west screenlines across the community or the subarea desired and to use the closest count for all streets bisected by the screenline. Another method, less exact, is to select counts at random. Still another is for an experienced traffic analyst to select typical counts. Regardless of the procedure used, all distributions should be examined by an experienced traffic professional for reasonableness. While city-specific data sources as described above are preferable, in some cases it may be necesssary to use published data on hourly distribution of traffic. Examples appear in Tables 5-4 and 5-5.

In HWYEMIS1, link speeds are an output of program SPEED or its equivalent in UROAD, which were discussed in Section 5.5. Area and land use types are used in connection with determining cold/hot start percentages, as discussed in Section 5.5.1.2. Facility type is used only to output a summary.

MOBILE1 inputs were treated in a previous section. The HWYEMIS1 program documentation gives instructions on how to input the necessary parameters when MOBILE1 is not run as an internal program within HWYEMIS1.

It should be noted that HWYEMIS1 does not compute intrazonal VMT related emissions since only VMT for interzonal links and centroids are generally coded on the historical record. Travel emissions for intrazonal trips may be included in the network emission model by inserting dummy links into each zone, or the number of intrazonal trips per zone may be multiplied by an average trip distance to develop a VMT figure (as discussed in Section 5.4) which is then multiplied by an emission factor. An emission factor is developed with MOBILE1. The only input modification from the MOBILE1 parameters used in the network emission model is speed. A speed commonly used, although undocumented, is 13 mph.

Table 5-4. HOURLY DISTRIBUTIONS OF AVERAGE DAILY TRAFFIC FOR LARGE CITIES AS A PERCENTAGE OF THE TOTAL

(Percent ADT for cities with >500,000 population)

Hour	Freeways			Arterials		
	CBD	Central City	Suburban	CBD	Central City	Suburban
0	1.5	1.5	1.5	1.5	1.5	1.5
1	1.0	1.0	1.0	1.0	1.0	0.5
2	0.5	0.5	0.5	1.0	0.5	0.5
3	0.5	0.5	0.5	0.5	0.5	0.5
4	1.0	0.5	1.0	0.5	0.5	0.5
5	2.0	1.5	1.5	1.5	1.0	1.0
6	5.5	4.5	4.5	3.5	4.5	4.0
7	8.5	7.5	8.5	6.5	8.0	7.5
8	7.0	6.5	6.5	6.5	6.0	5.5
9	4.5	5.0	5.0	5.0	4.5	4.5
10	4.0	4.5	5.0	5.5	4.5	4.5
11	4.5	4.5	4.5	5.5	5.0	5.0
12	4.5	4.5	4.5	5.5	5.0	5.0
13	4.5	5.0	4.5	6.0	5.0	5.0
14	5.5	6.0	5.5	6.5	5.5	6.0
15	7.5	7.5	7.0	7.0	7.0	7.0
16	9.5	9.0	8.5	8.5	9.0	8.5
17	8.0	8.5	8.5	7.5	8.0	8.5
18	5.0	5.5	5.5	4.5	5.5	6.0
19	4.0	4.0	4.5	4.0	5.0	5.5
20	3.5	3.5	3.5	3.5	4.0	4.5
21	3.0	3.5	3.0	3.0	3.5	3.5
22	2.5	3.0	2.5	3.0	3.0	3.0
23	2.0	2.0	2.5	2.5	2.0	2.0

Source: Reference 11

Table 5-5. HOURLY DISTRIBUTIONS OF DIRECTIONAL SPLIT FOR LARGE CITIES AS A PERCENTAGE OF HOURLY VOLUME

(Directional split, inbound, for cities with >500,000 population)

Hour	Freeways			Arterials		
	CBD	Central city	Suburban	CBD	Central city	Suburban
0	44	38	44	48	44	40
1	44	40	46	48	46	42
2	50	40	48	46	44	44
3	52	46	54	48	48	48
4	58	56	60	54	54	58
5	66	64	68	64	62	66
6	66	70	68	62	66	72
7	60	70	64	62	68	68
8	58	68	58	62	64	60
9	54	62	54	58	56	56
10	48	58	52	54	54	54
11	48	52	50	54	52	50
12	48	52	50	52	50	50
13	50	52	52	52	50	50
14	52	50	52	52	50	50
15	44	46	48	48	46	46
16	38	38	42	44	40	40
17	40	38	40	40	38	38
18	44	46	44	46	46	46
19	46	52	48	50	52	50
20	50	46	48	50	48	46
21	52	42	44	48	46	44
22	52	42	46	48	46	44
23	50	40	44	50	46	44

Source: Reference 11

5.6.1.2 APRAC-2

The APRAC-2 program and documentation are available from:

U.S. Environmental Protection Agency
Region IX
215 Fremont Street
San Francisco, California 94108

APRAC-2 continues to be revised by various organizations, so the user should be sure to obtain the latest version. Early versions contained Supplement 5 emission factors and several program errors. APRAC-2 is considerably more data intensive than HWYEMIS1. Data required are:

- Historical record data containing:
  - network description
  - speed by link (as an option, this can be computed with the volume/capacity method by the program)
  - traffic volume
  - land use type
  - area type
  - facility type
  - capacity, if speed is to be calculated by the program
- Secondary traffic data
- Ten sets of hourly traffic distributions for weekday traffic
- Seasonal traffic adjustment
- MOBILE1 input

Historical record data needed for APRAC-2 are similar to those needed for HWYEMIS1, with two exceptions. APRAC-2 can either use speeds from the historical record (program SPEED or the UROAD equivalent) or compute link speeds within the program using a volume/ capacity relationship. If the program option to compute link speed is used, capacity and free-flow speeds by facility type and locale are required. The facility types needed in APRAC-2 do not correspond to common FHWA indicators.

APRAC-2 incorporates the concept of secondary traffic, which is synonymous with intrazonal travel. If the user cannot calculate intrazonal VMT by the procedure outlined in the previous section on HWYEMIS1, APRAC-2 allows specification of the amount of secondary traffic in either of two ways. The first method allows specification of secondary traffic as a percentage of primary traffic (traffic on links). The second procedure allows specification of secondary traffic by locale. Both methods required an assumed regionwide ratio of primary to secondary traffic. The user should consult the APRAC-2 documentation for more detail on its handling of secondary traffic.

In APRAC-2, extensive data on hourly distributions, by direction and by locale, are required. Specifically, directional distributions for each locale are required. General procedures for developing hourly traffic distributions were included in the previous section on HWYEMIS1. Professional judgment of a traffic analyst is needed to develop these inputs.

A seasonal traffic adjustment figure is also an essential input to APRAC-2. Again, a traffic analyst should develop this regionwide figure. The adjustment figure should be based on monthly counts and weighted toward the area with highest traffic volumes. This value rarely exceeds 10 to 15 percent.

The MOBILE1 input parameters are the same as discussed for HWYEMIS1.

5.6.2 HYBRID MODELS

As mentioned previously, the hybrid approach, wherein trip-end and vehicle related emissions are calculated separately from travel related emissions, is potentially more precise than the link-based approach. To date, however, no standardized hybrid models are available for use in calculating network emissions. Some groups are developing their own hybrid models whereas others have modified SAPOLLUT to this end. EPA and DOT are jointly developing a hybrid model that will directly interface with the UTPS and PLANPAC/BACKPAC transportation batteries. Because no standard hybrid models are currently available, the concepts involved will be discussed only briefly here.

If the hybrid approach is used, only the travel related (i.e., hot stabilized) emissions from interzonal links and centroid links are considered in HWYEMIS1 or APRAC-2. If dummy links or the secondary traffic procedure in APRAC-2 are used, stabilized emissions from intrazonals may also be included. The remaining emissions to be included in the highway vehicle inventory are:

- Trip-end emissions - cold/hot transient starts
- Trip-end emissions - hot soaks, for LDV's only
- Vehicle related emissions
- Intrazonal trips (if not added earlier) - travel, trip, and vehicle related emissions

The basic process is simplistically described in the following paragraphs. For cold/hot transient starts, auto trip origins are determined by zone and by purpose for the desired time increments. Then, using tables in the FHWA report[7] (discussed in Section 5.5.1.2), the number of cold/hot transient starts are calculated by trip purpose. Finally, appropriate emission factors, representing excess emissions over hot stabilized operation, are multiplied by the number of cold/hot transient starts to estimate startup emission by zone. Examples of such factors, expressed as excess startup emissions in units of grams per trip, are presented in Reference 12.

Emissions from hot soaks are calculated for autos only. As with the startup component, truck trip-end related emissions are incorporated in the truck travel related emission rates. The required data input is the number of trip destinations in each zone. The number of destinations by zone is available from the origin/

destination trip table used in the cold start analysis (Section 5.5.1.2). Because hot soaks are usually thought to occur within one hour of engine shutdown, all destinations are usually considered to entail a full hot soak. Each hot soak is multiplied by the appropriate emission factor to estimate hot soak emissions per zone. Examples of hot soak factors, in units of grams per trip, are also shown in Reference 12.

Vehicle related (diurnal) emissions are simply a function of the number of vehicles in the study area. The number of vehicles is best obtained from state registration data. Once the total number of vehicles for the analysis area is known, emission factors such as those presented in Reference 12 (in terms of grams per day per vehicle) are used to produce total vehicle related (diurnal) emissions.

If travel related emissions for intrazonal trips are not included in the network emission model by inserting dummy links into each zone, they must be added in this step. The total number of intrazonal trips in each zone is multiplied by an average trip distance, which can be zone specific if the computational capacity is available. An emission factor is developed using MOBILE1.

To calculate emissions from intrazonal starts, the number of trip origins in each zone are needed along with cold/hot transient start percentages and emission factors representing excess emissions per cold/hot start. The number of trip origins is known from the previous step. Cold/hot transient start percentages must be developed by the analyst. No good sources of this data are available because the intrazonals are, by definition, short trips. The percentage would be expected to be higher than those specified in Table 5-3.

Intrazonal hot soak emissions are determined, in the hybrid approach, by multiplying appropriate hot soak emission factors by the number of trip destinations. By definition, for intrazonal trips, the number of trip destinations in a zone equals the number of trip origins; hence, the number of intrazonal trip origins may be used, as determined above.

Vehicle related (diurnal) emissions from intrazonal trips need not be accounted for separately as these emissions will be included in the calculation based on areawide vehicle registrations.

5.7 HIGHWAY VEHICLE EMISSION GRIDDING PROCEDURE

Referring again to Figure 5-1, the last step necessary prior to completing the detailed highway vehicle emission inventory is to convert all link emissions to the grid system to be used in the photochemical model.

Because link-based and hybrid network models compute highway vehicle emissions differently, some procedural differences will exist in this link/zone-to-grid-cell conversion step. Each type of model is discussed separately in the following sections.

5.7.1 GRIDDING PROCEDURES FOR LINK-BASED MODELS

Currently, neither the PLANPAC/BACKPAC nor UTPS program batteries contains adequate programs to convert link emissions to gridded emissions. SAPLSM (PLANPAC/BACKPAC) and UROAD (UTPS) are the available gridding programs but, in both cases, no more than 50 grid cells can be managed. APRAC-2 can output emissions for 625 grid cells. This may be adequate spatial resolution in some applications, but a greater number of cells are required in most cases. Thus, the agency responsible for compiling the inventory will have to develop this programming capability. Several MPO's have written programs that provide this function. All programs follow the same basic principles. Link emissions are apportioned to grid squares by assuming that the emissions are uniformly distributed along a straight line. The fraction of the line segment that falls within a given grid square determines the fraction of the total emissions for the link that fall in that square. The contributions of all links are summed for each square.

There are two basic requirements for the conversion of link emissions to gridded emissions. The first is a grid system with coordinates; the second is a compatible coordinate system for the links. In most areas, air quality agencies compile emission inventory data with UTM coordinates. Traffic studies, while often having geographical coordinates coded onto the historical record, seldom use UTM coordinates. Therefore, in most cases, the two coordinate systems are incompatible. A specially written program is required for conversion to UTM coordinates. As with the gridding program, several agencies have developed their own programs which can be modified to individual system requirements. With compatible coordinate systems, a preprocessor program is required that determines the percent of each link included in each grid cell.

Intrazonal emissions, if not determined by coding dummy links on the historical record, will be calculated at the zonal level, as described in previous sections. In this instance, a zone-to-grid-cell conversion program is necessary. Again, as with the link-to-grid-cell conversion, no standard programs are available that are compatible with the UTPS and PLANPAC/BACKPAC batteries. Hence, the agency will have to develop its own programs. Several local agencies have done this.

5.7.2 GRIDDING PROCEDURES FOR HYBRID MODELS

The travel related (hot stabilized) emissions calculated by hybrid models for links are assigned to grid cells in the same manner as in link-based models. Likewise, the travel related emissions associated with intrazonal VMT are also handled similarly. The major difference is that trip-end emissions (in Section 5.6.2) yield emissions for each zone. Hence, the zone-to-grid-cell conversion procedures described above can be used for this conversion.

The procedure outlined in Section 5.6.2 for computing vehicle related (diurnal) emissions results in total emissions for the study area. The problem is then one of allocation. Theoretically, vehicle emissions occur throughout the time period during which the temperature is rising, usually considered to be 6:00 a.m. to 3:00 p.m. The emissions occur regardless of whether the vehicle is parked or running. Therefore, these emissions should be spatially allocated to zone, according to the vehicle minutes spent in each traffic zone. Ordinarily, however, available data are not sufficient to determine this spatial distribution. Parking data may be used, but they may be of questionable accuracy and relevance. Lacking better information, a practical approach is to use either VMT or travel related emissions as a surrogate indicator for gridding.

5.8 TRANSPORTATION CONTROL MEASURE ANALYSIS

An important part of the photochemical modeling effort is the evaluation of alternate control strategies. For this purpose, projection inventories must be compiled for each proposed set of control measures. Table 5-6 shows examples of various transportation control measures that may be considered for reducing highway ve-

Table 5-6. EXAMPLE TRANSPORTATION CONTROL MEASURES

- Vehicle inspection and maintenance
- Vapor recovery from fuel transfer and storage and from solvent operations
- Improved public transit
- Exclusive bus and carpool lanes
- Areawide carpool programs
- Restrictions on private automobile use
- Long-range transit improvements
- On-street parking controls
- Park-and-ride and fringe parking lots
- Pedestrian malls
- Employee programs to encourage car- and vanpooling, mass transit use, bicycling, and walking
- Bicycle lanes and storage facilities
- Staggered work hours
- Road pricing to discourage single occupancy automobile use
- Controls on extended vehicle idling
- Traffic flow improvements
- Fleet vehicle controls including alternative fuels and engine use
- Vehicle retrofits for other than light duty vehicles
- Extreme cold start emission reduction programs

Source: Workshop on Requirements for Nonattainment Area Plans, Compilation of Presentations, Revised Edition, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, April 1978.

hicle emissions. There are two basic types of control strategies involving highway vehicles: (1) those that can be simulated by making emission factor changes (e.g., in MOBILE1) and (2) those that result in traffic pattern changes, i.e., changes in the magnitude of VMT, spatial and temporal VMT patterns, etc.

Measures related to emission factor changes are easily accommodated by the processes described in this chapter. For example, MOBILE1 contains a provision for considering the I/M control program. The user specifies a year, the stringency of I/M mechanics' training, and the model years to which I/M applies. When running the emissions model, which in this case is contained within the network emission model (HWYEMIS1 or APRAC-2), MOBILE1 parameters that include I/M are specified and the procedure continues as described. As another example, the composite emission factors projected by MOBILE1 automatically incorporate the emission reductions mandated by the Federal Motor Vehicle Control Program; however, alternate rates of implementation of these standards can be considered.

Measures resulting in traffic pattern changes are much more difficult to simulate. The basic problem is one of changing link volumes from the transportation models to reflect results of the control measures, yielding new link volumes which are then input to the network emission model. Methods to estimate the changes in link volumes vary widely in both approach and complexity. Some measures can be simulated within the PLANPAC/BACKPAC and UTPS program batteries. These measures include such things as traffic flow improvements and pedestrian malls (auto-free zones). The basic approach is to change the link description. For example, in the case of traffic flow improvement that consists of street widening, the capacity of the link on the roadway is increased. In the traffic assignment process, the volume/capacity relationship is changed, increased volume is assigned to the link, and the speed is recalculated. When input to the network emission model, a new link volume and a new link speed are incorporated; the change in link speed results in a revised emission factor.

Other measures resulting in traffic pattern changes cannot be simulated with the PLANPAC/BACKPAC and UTPS batteries. These are the measures that require a modal choice such as transit use, carpooling, bicycling, and walking. While the UTPS system does contain some transit choice capability, policy-sensitive disaggregate demand models [12, 13, 14] are required in most cases. Demand levels between alternate choices are estimated by the disaggregate models, and volumes and speeds input to the network emission model are changed accordingly. These disaggregate models represent the state-of-the-art method for analyzing such measures as CBD parking surcharges, carpool programs, park-and-ride facilities, etc. For more information on the simulation of specific transportation control measures, the reader should consult References 12 through 14, and numerous other publications on the subject.

References for Chapter 5.0

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6.0 AREA SOURCES

6.1 GENERAL

Except for highway vehicle emissions, the basic annual countywide inventory is a good starting point for developing the detailed photochemical modeling inventory for most other area sources. Generally, the basic inventory should contain activity level and emission estimates for many of the following area sources of VOC or NO_x:

- Aircraft
- Railroads
- Vessels
- Other Off-Highway Vehicles (farm tractors, construction equipment, lawn mowers, etc.)
- Gasoline Handling
- Drycleaning
- Degreasing
- Nonindustrial Surface Coating
- Cutback Asphalt
- Pesticides Applications
- Miscellaneous Solvent Use
- Oil and Gas Wells
- Onsite Incineration
- Open Burning
- Residential Fuel Use
- Commercial/Institutional Fuel Use
- Forest Fires
- Slash and Agricultural Field Burning
- Structural Fires

Of course some of the above source categories, as was discussed in Volume I, may be treated as point sources in the basic inventory and some may be handled as both point and area sources depending on the cutoff level used for making this distinction. Likewise, a number of other source categories that traditionally are considered to be point sources may, at least in part, be treated as area sources. Industrial fuel use, industrial surface coating, and gasoline bulk tanks are examples of this type of source category. The inventorying agency should be aware of all such distinctions and may need to institute certain changes prior to completing the detailed photochemical modeling effort. For example, if the agency needs to make a detailed analysis of the effect of controlling drycleaning operations, it may prefer to treat each plant as a point source rather than collectively as part of an area source, as this would allow distinct control measures to be evaluated for each plant. Conversely, if drycleaning plants were treated as point sources in the existing basic inventory, but no specific information was available on growth at specific locations, the agency might wish to treat drycleaning as an area source in the detailed inventory. It is generally recommended, however, that the point/area source distinctions made in the basic inventory be utilized in the detailed inventory to minimize additional resources needed.

In the basic inventory, emissions are generally determined over a broad area, such as each county within an urban area. A primary reason for this is that estimates of the activity levels used in calculating area source emissions are generally available at the county level. Moreover, these estimates typically represent annual, or, in some cases, seasonal emissions, and do not distinguish between different reactive classes of VOC and NO_x. These area source estimates can be used in the photochemical modeling inventory; however, as with point sources, several additional steps need to be taken by the inventorying agency in order to provide the spatial, temporal, and species resolution required of the detailed inventory. First, the countywide emission estimates for area sources must be allocated to the grid cell level. Second, hour-by-hour emission estimates must be developed for a typical weekday during the oxidant season. Third, VOC emissions for each source will have to be apportioned into classes; in some models, NO_x emissions will have to be distinguished as NO and NO_2. Techniques for providing the necessary spatial and temporal resolution in the photochemical modeling inventory are prescribed in general in Sections 6.2 and 6.3, respectively. Specific recommendations are given in Sections 6.5 through 6.16 for several of the more important area source categories. Chapter 7 presents procedures for apportioning area source emissions into classes.

6.2 GENERAL METHODOLOGY FOR SPATIAL RESOLUTION

As mentioned in Chapter 2, photochemical models require that all emissions be resolved to the grid cell level. Either of two approaches can be employed to accomplish this task. In certain cases, the agency may be able to determine the activity levels and emissions of some area sources directly for each grid cell. More commonly, it will be necessary to apportion the countywide emissions to the grid cell level by assuming that the distribution of such area source activity behaves similarly to some surrogate indicator. Both approaches are discussed herein.

6.2.1 DIRECT GRID CELL LEVEL DETERMINATION OF EMISSIONS

In limited instances, sufficient information may be available to the air pollution agency to calculate area source activity levels and emissions directly at the grid cell level. This would primarily be the case where sufficient information is available on individual facilities such that they could be considered as minor point sources in the annual inventory; however, for various reasons, the agency has chosen to consider them collectively as an area source. One example of this situation is where a local gas company has information on the quantity of natural gas fired in every household or commercial establishment. This situation may also arise when survey results are available on a particular type of commercial or industrial establishment. For instance, a survey may have been conducted resulting in information on the sales and location of each gasoline service station in the modeling area. Hence, in the photochemical modeling inventory, instead of aggregating gasoline sales and calculating emissions at the county level, as may be done in the annual inventory, gasoline sales can be aggregated and emissions calculated directly for each grid cell. When emissions are calculated directly at the grid cell level, the resulting emission totals are potentially more accurate than if calculated at the county (or equivalent) level.

Of course, another option available to the agency if this type of survey information is available is to "reassign" each facility as a point source in the detailed, photochemical modeling inventory. This latter course might be advantageous if the agency is considering implementing a control measure that can best be evaluated if each facility within the source category is treated as a point source. An obvious disadvantage in doing this is that many additional point source records would have to be generated and maintained both in the base year and projection inventories. In this latter regard, it is generally much easier to handle numerous, small establishments as area sources in projection inventories than as point sources - especially if information is not available on the location of each facility in the projection years.

6.2.2 SURROGATE INDICATOR APPROACH

When area source activity levels and emissions cannot be determined directly at the grid cell level, surrogate indicators must be specified whose distribution is known at some subcounty level and which behave similarly to the activity levels of interest. These surrogate indicators are then applied to the basic, countywide inventory to apportion activity levels or emissions to each grid cell. The variables most commonly used as surrogate indicators of area source activity are land use parameters, employment in various industrial and commercial sectors, population, and dwelling units. Different surrogate indicators will be used for various area source categories, of course, depending on which one best describes the spatial distribution of the emissions and on what information is available for the modeling area. Engineering judgment is most often used to select the appropriate indicators for apportioning area source emission totals. Table 6-6 suggests appropriate surrogate indicators for various area source categories, as utilized in various urban areas.

Two basic sources of information on surrogate indicators are (1) land use and other maps, and (2) Census Bureau demographic statistics by traffic zone. Both sources may be used in the photochemical modeling inventory to develop apportioning factors, as discussed herein.

6.2.2.1 Developing Apportioning Factors From Land Use Maps

Most urban areas large enough to apply photochemical models will have land use maps available for the present and several projection years. These maps can be used by the air pollution control agency to develop apportioning factors for those area sources whose emissions will be distributed based on various land use classifications.

This procedure is best illustrated by use of an example. Assume that the existing inventory contains an estimate of total emissions from drycleaning for the entire area, and no specific survey or other information is available for individual drycleaning establishments. A surrogate indicator must be chosen that will permit the distribution of these emissions among the individual grid cells in the study area. For making distributions at a subcounty level, a land use map supplied by a local planning agency is often the best available tool. The land use map cartographically characterizes each part of the study area in terms of what kinds of activities are predominant in that area. Figure 6-1, for example, shows a land use map of a part of the Tampa Bay, Florida region. The various areas are identified in great detail by numbers; Table 6-1 exhibits the coding system used in this application. Other land use maps may use colors or shading techniques to differentiate areas.

Since drycleaning is a typical commercial activity, it is reasonable to assume that drycleaning area source emissions emanate uniformly from the commercial areas as shown on the land use map. Thus, the surrogate indicator will be the area devoted to commercial land use (represented in Figure 6-1 by codes 12 and 15). In this approach, it is necessary to estimate the area within each grid cell which is designated as a commercial area on the land use map. For this purpose, the grid system network must be superimposed on the land use map, as shown in Figure 6-1. The estimates of land use area in a grid cell can be fairly rough (e.g., to the nearest tenth of a grid cell). As an example, consider the grid cell designated (15,15) in Figure 6-1. For this grid cell, about 20 percent of the area is indicated as commercial (code number 12), while the remaining 80 percent of the grid cell is designated as single-family residential (code number 11). If a grid cell contains an area designated by code number 15 (industrial and commercial combined), such an area may be weighted at 50 percent in this computation.

The emissions for each grid cell are then estimated as a simple fraction of the total, as follows:

$$E_i = E_T (S_i/S_T)$$

where

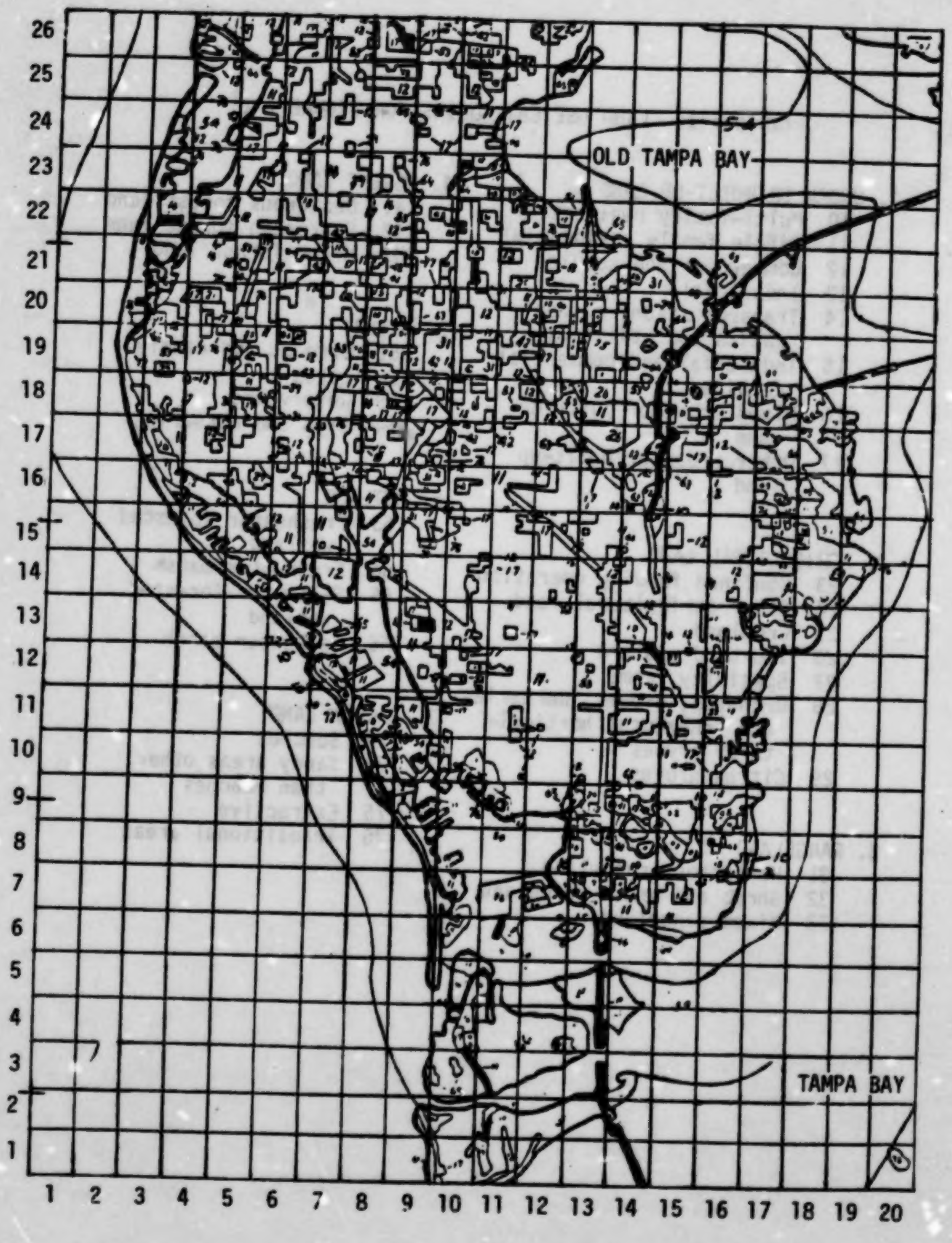
E denotes emissions

S indicates surrogate indicator,

i indicates the value in grid cell i

and

T indicates the total for the county or region


OLD TAMPA BAY
TAMPA BAY
26
25
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12
11
10
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2
1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Figure 6-1. Segment of Land Use Map for Tampa Bay, Florida

Table 6-1. LAND USE CATEGORIES FOR FIGURE 6-1[1]

1. URBAN OR BUILT-UP LAND
   - 10 Multi-family residential
   - 11 Single family residential
   - 12 Commercial and service
   - 13 Industrial
   - 14 Transportation, communication and utilities
   - 15 Industrial and commercial combined
   - 16 Mixed urban or built-up land
   - 17 Other urban or built-up land

2. AGRICULTURAL LAND
   - 23 Confined feeding operation
   - 24 Other agricultural land
   - 25 Cropland
   - 26 Improved pasture
   - 27 Specialty farms
   - 28 Orchards, groves, nurseries and ornamental horticultural groves
   - 29 Citrus groves

3. RANGELAND
   - 31 Herbaceous rangeland
   - 32 Shrub and brush rangeland
   - 33 Mixed rangeland

4. FOREST LAND
   - 41 Deciduous forest land
   - 42 Evergreen forest land
   - 43 Mixed forest land

5. WATER
   - 51 Streams and canals
   - 52 Lakes
   - 53 Reservoirs
   - 54 Bays and estuaries

6. WETLAND
   - 63 Freshwater forested wetland
   - 64 Freshwater marsh
   - 65 Saltwater forested wetland
   - 66 Saltwater marsh

7. BARREN LAND
   - 72 Beaches
   - 73 Sandy areas other than beaches
   - 75 Extractive
   - 76 Transitional areas

The units for the surrogate indicator can be arbitrary (e.g., percent of grid cell, square kilometer, square mile). For example, assume that the total commercial area in Figure 6-1 covers an area the size of 26.3 grid cells. Then the fraction of the total commercial area (S_i/S_T) for grid cell (15,15) will be 0.2/26.3, or 0.0076. (This fraction is known as an "apportioning factor.") Thus, the emissions for drycleaning attributed to grid cell (15,15) will be 0.0076 times the total drycleaning emissions from the entire region. Mathematically, this can also be expressed by the equation

$$f_{i,k} = S_{i,k} / \sum_{i=1}^{n} S_{i,k}$$

where

$f_{i,k}$ is the apportioning factor for grid cell i with respect to source category k, and

n is the total number of grid cells.

Other maps, if reasonably current, can be used to develop apportioning factors for various area sources. United States Geological Survey (USGS) maps, for example, show the location of oil and gas wells. By counting the number of wells per grid cell, total oil and gas well emissions can be apportioned by multiplying them by the fraction of wells lying in each grid cell. (In this case, the number of wells serves as the surrogate indicator of production activity.) Similarly, USGS maps show railroad track mileage by grid cell, which may be used to develop apportioning factors for railroad emissions. A disadvantage of developing apportioning factors from maps other than land use maps is that corresponding projection information will often not be available for allocating future year emissions. In these cases, the air pollution control agency will either have to (1) assume that projection year emission patterns of these sources will not change, or (2) locate additional information that shows what changes are expected in these surrogate indicator distributions.

The foregoing discussion has only dealt with the allocation of area source emissions based on a single surrogate indicator. There may be cases where the agency feels that no one parameter accurately describes the subcounty distribution of emissions from a particular area source category. In these cases, apportioning can be based on two or more surrogate indicators. For example, since miscellaneous solvent use can be associated with both consumer (residential) and commercial applications, the agency may wish to distinguish between the possible different rates of use in these land use categories (10, 11, and 12 of Table 6-1).

There are two principal ways to manage this type of apportionment. First, the agency may estimate solvent emission subtotals for three types of land use involved, then apportion each of these subtotals according to the corresponding land use areas. (In effect, this creates three new emission subcategories where the countywide inventory may have had only one.) For example, the agency might choose to assign one third of the miscellaneous solvent emissions to multifamily residences (land use 10), one third to single family residences (land use 11), and one third to commercial and service use (land use 12). Hence, if countywide emissions from miscellaneous solvent use are 12 tons per day, 4 tons per day would be apportioned at the grid cell level for each of these subcategories, based on the distribution of the corresponding surrogate indicator. Alternatively, the agency might decide to estimate the relative intensity of solvent use in the three types of areas. For example, assuming single-family residential areas have the smallest emission rate per unit area, the agency might estimate that the emission rate in multiple family residential areas is three times as large, and in commercial and service areas, five times as large. In this case, the apportioning factors would be calculated using an appropriate weighting factor for each of the three types of land use. This would be expressed, mathematically, by the equation

$$f_{ik} = \sum_{j=1}^{3} W_{jk}S_{ij} \qquad \sum_{i=1}^{n} \sum_{j=1}^{3} W_{jk}S_{ij}$$

where

W_{jk} is the weighting factor selected for land use type j in relation to source category k.

S_{ij} is the value of the surrogate indicator (i.e., the area) of land use type j in cell i.

In this application, the summation term appearing in the numerator is essentially a composite surrogate indicator for the entire category. Thus, if solvent emissions are weighted according to the previous suggestion ($W_1 = 1$, $W_2 = 3$, $W_2 = 5$) and the respective areas in a given grid cell are 0.6, 0.2, and 0.2, then the value of the composite surrogate indicator for that cell is 0.6 x 1 + 0.2 x 3 + 0.2 x 5, or 2.2. The entire category is then apportioned as usual, based on this composite surrogate indicator.

6.2.2.2 Developing Apportioning Factors From Demographic Statistics at the Traffic Zone Level

As part of the transportation planning process routinely performed in larger urban areas, employment and other demographic statistics are aggregated at the zonal level. These statistics can be used instead of land use maps to obtain the information needed to apportion area source emissions to the subcounty level. In theory, the same data contained in these zonal statistics are available from land use maps; thus, the only difference in using one approach or the other is procedural. In practice, however, the land use maps that are typically prepared in certain areas may not show all the detail available in these zonal statistics. For instance, zonal statistics in a particular urban area may typically be compiled for five or more commercial and industrial subcategories; however, the corresponding land use maps may only identify generalized commercial and industrial land uses. Also if land use maps are used for developing apportioning factors, the manual step of coding land use data for each grid cell must be repeated for every growth projection. If zonal statistics are used, however, this process can be largely automated once a set of zone-to-grid-cell conversion factors has been developed. These conversion factors are discussed later in this section. The data handling aspects of utilizing zonal statistics are discussed in more detail in Chapter 8.

The following example illustrates the use of detailed zonal statistics for developing allocation factors as well as the use of multiple surrogate indicators to apportion emissions from a number of area source categories. In the San Francisco Bay area of California, emissions from 58 area sources are apportioned using combinations of the 19 demographic parameters shown in Table 6-2, all of which are compiled at the subcounty level by the local MPO as part of transportation planning studies. For some area source categories, a single parameter from Table 6-2 is used as a surrogate indicator of the distribution of emissions. For instance, the source category "farming operations" is linked with the single employment category "AGRI" from Table 6-2, which includes agriculture production and services. Similarly, the source category "printing" is distributed with the variable "MFGI," which includes printing, publishing, and related industries. However, emissions from other area source categories are not felt to be accurately distributed by a single variable. In these instances, emissions are apportioned based on two or more parameters. An excerpt from a cross-classification table used in the Bay Area is presented in Table 6-3, which

Table 6-2. DEMOGRAPHIC PARAMETERS USED IN SAN FRANCISCO BAY AREA FOR MAKING ZONAL ALLOCATIONS OF AREA SOURCES[2]

Variable[a] Name	SIC[b] Classification	Description
DWELL	(not applicable)	Dwelling units
AGRI	1, 7-9	Agriculture, forestry
MIN	10, 13, 14	Mining, quarry, oil and gas extraction
MFG1	27	Printing, publishing
MFG2	26, 28, 29, 32, 33	Petrol., chem., paper, metal industries
MFG3	20	Food and kindred products
MFG4	19, 36, 38	Electrical, optical, machinery & instruments
MFG5	34, 35, 37	Fabricated metal products
MFG6	22-25, 31, 39	Textiles, apparel, wood, leather
TRAN	40, 42, 44-46	Transportation (non-auto), pipelines
WHOL	50, 52	Wholesale trade, building material
FIN	62, 63, 67	Financial, insurance
SERV 1	73	Business services
SERV 2	82, 84, 89	Educ. service, museums, galleries
GOV	91, 92	Government
RET	53-59	General merchandise & food stores
BUS. SERV.	80, 81, 96	Health, legal, admin. services
RET. SERV.	70, 72, 75-79	Hotels, personal service, repairs
OTHER SERV.	15-17, 41, 47-49, 60 61, 66, 93-95, 99	Construction, transit, utilities, banking, real estate, other

[a] The variable referred to is the employment, totalled in each zone, for the SIC classifications listed in the next column. (DWELL is an exception, as described in Column 3)

[b] Standard Industrial Classification Code

Table 6-3. EXCERPT FROM ABAG CROSS CLASSIFICATION TABLE USED IN SAN FRANCISCO BAY AREA FOR SUBCOUNTY ALLOCATION OF AREA SOURCE ACTIVITIES[2]

Source Classificaton	1 DWELL	7 AGRI	8 MIN	9 MFG1	10 MFG2	11 MFG3	12 MFG4	13 MFG5	14 MFG6	15 TRAN	16 WHOL	17 FIN	18 SERV1	19 SERV2	20 GOV	21 RET	22 BUS SERV	23 RET SERV	24 SERV OTHER
CHEMICAL																			
Misc. Chem. Proc.																			
OTHER IND./COM.																			
Metallurgical					90			10											
Mineral - Concrete					100														
Mineral - Stone, Sand & Gravel	10		40		50														
Mineral - Sand Blast					10			5		10	5	5	5	10	10	10	10	10	10
Misc. Mineral Proc.			10		90														
Farming Operations		100																	
Food/Agric. Proc.						100													
Paint Spray Mist	5				10			70										15	
Wood Products Mfg.	10								80									10	
Misc. Inc./Com. Proc.							30	30	30									10	
GASOLINE DISTRIB.																			
Vehicle Fill Sta. -																			
- Spillage										5						90			5
- Storage Tanks										5						90			5
- Veh. Tanks										5						90			5
OTHER ORG. COMP. EVAP.																			
Storage Tanks -																			
- Solvent					20		20	20	20	10	5							5	
- Misc. Org. Comp.		5	10		20	15	10	10	10	10	5								5
Ind. Coat.-Solv. Base				10	10		10	50	10									10	
Ind. Coat.-Water Base								90	5									5	
Com. & Dom. Coat.																			
- Solv. Base	64	3	3							3	3	3	3	3	3	3	3	3	3
- Water Base	64	3	3							3	3	3	3	3	3	3	3	3	3
Degreasers							10	60										20	10
Drycleaners - PERC																		100	
Drycln-Misc. Solv.																		100	
Rubber Fabrication					100														
Plastic Fabrication					90													10	
Printing				100															
Misc. Org. Evap.	10	5	5		50		5	5	5									10	5

shows the percentage of each area source emission total that is apportioned by each demographic parameter.

To continue this example, assume that area source degreasing emissions in a given county are 42 tons/day of VOC. According to Table 6-3, 10 percent of this total should be apportioned according to the distribution of employees engaged in the manufacture of electrical and optical machinery and instruments (MFG4), 60 percent based on fabricated metal product employment (MFG5), 20 percent based on retail service employment (RET SERV.), and 10 percent based on other services, including local transit and transportation services (OTHER SERV.). Thus, 4.2 ton/day (42 x 0.10) are apportioned according to the fraction, in each grid cell, of the total number of employees in the "MFG4" category; 25.2 ton (42 x 0.60) are apportioned according to the fraction, in each grid cell, of the total number of employees in the "MFG5" category; 8.4 ton (42 x 0.20) apportioned according to the fraction of employees in each grid cell in the "RET. SERV." category; and 4.2 ton (42 x 0.10) apportioned according to the fraction of "OTHER SERV." employees in each grid cell. For instance if the i^{th} grid cell contains 0.1 percent of the total areawide "MFG5" employees, 0.05 percent of the "RET. SERV." employees, 1 percent of the "MFG4" employees, and no "OTHER SERV." employees, then the degreasing emissions would be apportioned to that grid cell as follows:

$$
\begin{aligned}
i^{th} \text{ Grid Cell Emissions} &= 25.2 \times 0.001 + 8.4(0.0005) \\
&\quad + 4.2(0.01) + 4.2(0) \\
&= 0.0714 \text{ ton/day}
\end{aligned}
$$

The degreasing emissions for the other grid cells would be apportioned accordingly, as would the emissions for the other area sources. An equivalent formulation of this procedure is simply to subdivide the area source degreasing category into four subcategories, namely, (1) degreasing, MFG4; (2) degreasing, MFG5; (3) degreasing, RET SERV.; and (4) degreasing, OTHER SERV. Then, if the agency has estimated the total countywide degreasing emissions for these subcategories as 4.2, 25.2, 8.4, and 4.2 ton per day, respectively, these amounts will be allocated in the appropriate subcategories, using the corresponding demographic parameter as the surrogate indicator in each case.

In the preceding apportioning calculation, it is assumed that apportioning factors are compiled at the grid cell level. In actuality, as was pointed out at the outset of Section 6.2.2.2, the surrogate indicators (such as the demographic parameters shown in Table 6-2) used for apportioning are initially compiled at the zonal level for transportation and other planning purposes, and not at the grid cell level. For example, in the San Francisco Bay area, the local MPO develops its population, land use, and employment data for 440 zones, each of which comprises one to seven census tracts. By contrast, there are some 5,000 grid cells to which area source emissions are apportioned for photochemical modeling purposes.[2]

Thus, if zonal statistics are used for apportioning area source emissions, the air pollution control agency is confronted with the task of making a zone-to-grid-cell conversion prior to completing the apportioning steps. This step will not be required if apportioning factors are developed from land use maps because when this is done, the grid system is overlaid onto the land use map and the values of each surrogate indicator are directly determined for each grid cell by visual means.

The first steps in this zone-to-grid-cell conversion process are (1) overlaying a map outlining the grid system over a map showing the zone boundaries, and then (2) determining or estimating fractions of zonal area lying within specific grid cells.

To determine the fraction of the area of a given zone which lies within a given grid cell, it is useful to develop a zone-to-grid-cell correspondence table, such as that shown in Table 6-4. For each zone, the area falling in each grid cell is estimated in terms of the fraction (A) of the grid cell covered by that zone; then, the total of these fractional areas for all of the affected grid cells (ΣA) is the total area of the zone. (An exception must be noted in case a part of the zone lies outside the emission grid.) For each grid cell, the appropriate fraction (g) of the given zone is obtained by dividing the fractional area of intersection by the total area of the zone. The contribution of the zonal emissions to the grid square can be obtained by multiplying the zonal emissions (in any or all categories) by this fraction.

The next step in this zone-to-grid-cell conversion process is to multiply the latter fractions ($\underline{g}$) by the known zonal values of each demographic parameter in order to reaggregate the data at the grid cell level. Mathematically, this process may be expressed as follows:

$$a_{ik} = \sum_{j} g_{ij} b_{jk},$$

where

a_{ik} is the value of the k_{th} demographic parameter, reaggregated to grid cell $\underline{i}$;

b_{jk} is the value of the k_{th} demographic parameter, as compiled for zone $\underline{j}$;

g_{ij} is the fraction of area of zone $\underline{j}$ in cell $\underline{i}$.

Table 6-4. ILLUSTRATIVE EXCERPTS FROM ZONE-TO-GRID-CELL CORRESPONDENCE TABLE FOR DETERMINING APPORTIONING FACTORS

Zone										Total, ΣA
1	GC	0101	0102	0103	0201	0202	0301	0401		5.2
	A	1.0	1.0	0.7	1.0	0.5	0.7	0.3		
	g	.19	.19	.13	.19	.10	.13	.06		
2	GC	0103	0104	0202	0203	0204	0301	0303	0304	3.9
	A	0.3	1.0	0.5	1.0	0.6	0.2	0.2	0.1	
	g	.08	.26	.13	.26	.15	.05	.05	.03	
17	GC	0514								0.6
	A	0.6								
	g	1.0								
18	GC	0514	0614							0.3
	A	0.1	0.2							
	g	0.33	0.67							
23	GC	0624	0625							0.9
	A	0.3	0.6							
	g	0.33	0.67							

Legend: GC = grid cell number
A_{ij} = area of intersection of zone with grid cell
g_{ij} = apportioning factor from zonal level to grid cell (all activities assumed uniform throughout zone)

Further, g_{ij} is determined by

$$g_{ij} = A_{ij} / \sum_i A_{ij}$$

where

A_{ij} is the fractional area of intersection of zone j with cell i, in terms of the fraction of cell i covered by zone j.

To calculate apportioning factors from the county level to the grid cell level, the grid cell parameters must be normalized to the total for the county, i.e.,

$$f_{i,k} = a_{ik} \Big/ \sum_i a_{ik}$$

The same normalizing factor can, of course, be obtained by totaling the zonal values; that is, $\sum_i a_{ik} = \sum_j b_{jk}$, except for necessary corrections for any zone which falls partly outside the county. These apportioning factors ($f_{i,k}$) are then applied in an identical manner as the (S_i/S_T) factors described on page 6-6 that were determined from land use or other maps.

The most difficult part of this zone-to-grid-cell conversion process is the determination of the $g_{i,j}$ fractions. This step must generally be performed manually because the irregular nature of zonal boundaries in most urban areas complicates the computerization of this assignment. (However, the rest of the above calculations are readily automated.) One important assumption that should be kept in mind when estimating these $g_{i,j}$ fractions in this zone-to-grid-cell conversion step is that the distribution of each demographic parameter is uniform within each zone. In situations where zones are much larger than the coincident grid cells, this assumption can lead to erroneous distributions if most activity within particular zones actually takes place on one side or the other. Hence, prior to use, some review of the resulting correspondence table values should be made by local planners or others knowledgeable with the land use patterns in the urban area. In select cases, more activity might be distributed to one or several grid cells rather than being distributed to all grid cells simply on the basis of area. Generally, however, since zones are defined as areas of similar activity, this should not be a major consideration to the inventorying agency in most instances.

6.3 GENERAL METHODOLOGY FOR TEMPORAL RESOLUTION

Since the basic area source inventory will generally only contain estimates of annual (or perhaps seasonally adjusted) emissions, additional effort is needed in order to estimate hour-by-hour emission rates. Several approaches can be employed to develop hourly emissions resolution; all involve the use of assumed diurnal patterns of activity. Moreover, in addition to hourly patterns, estimates will be needed of the fraction of annual (or seasonal) operations for each area source that occurs on typical weekdays during the oxidant season.

The first step in this process, if only annual emission estimates are available from the countywide inventory, is to estimate the seasonal component of activity for each area source. For many sources, activity is fairly constant from season to season. For example, degreasing operations would not normally have a strong seasonal component, and hence, degreasing activity in the July-September quarter could be assumed to be 25 percent of the annual total. For some sources, a strong seasonal component will be evident. For instance, off-highway vehicles such as farm tractors, lawn mowers, etc., will be most active in the warmer months of the year, as will cutback asphalt paving operations. Conversely, residential fuel use will occur primarily in the colder winter months. In this latter case, it may be reasonable to assume no such fuel use during the oxidant season. Seasonal adjustment is discussed in detail in Chapter 7 of Volume I.

Once the seasonal component is known, the daily component should be determined. Again, some area source activities are fairly constant from day to day, making it a simple matter to estimate daily activities. For example, gasoline storage losses and natural gas leaks would be expected to be uniform over the week. Many work-related area sources, on the other hand, would be more active on weekdays. For instance, drycleaning plants and degreasing operations will concentrate their activities during Monday through Friday (or Saturday, in some cases). Hence, in these instances, the seasonal activity should be distributed to only those days on which the source is active. If, hypothetically, drycleaning emissions for the entire area are 312 tons of solvent over the 92-day period from July to September, and most plants are typically open 6 days a week (for a total of 78 operating days), then daily emissions from drycleaning would be 4 tons (312 ÷ 78). This daily emission rate would not, of course, be applicable to a Sunday. As explained in Chapter 2, photochemical models are usually run for weekday conditions.

After the daily activity level has been determined for each area source, the next step is to estimate hourly emissions. This is generally accomplished by applying a 24-hour operating pattern to the daily activity level. An example of this is shown in Table 6-5 for gasoline service stations. As seen in this table, more gasoline is handled in the Tampa Bay area in the afternoon than other times in the day. For instance, 13 percent of the daily operation in large stations occurs from 4 to 5 o'clock; hence, 13 percent of the daily emissions from large service stations would be assigned to

Table 6-5. DIURNAL PATTERNS FOR GASOLINE STATIONS IN TAMPA BAY, IN PERCENT OF DAILY OPERATION[1]

Hour	Type of Gasoline Station[a]		
	Small	Medium	Large
6-7 a.m.	5	4	8
7-8	6	4	8
8-9	6	6	8
9-10	5	5	7
10-11	6	7	2
11-12	6	7	2
12-1 p.m.	5	7	8
1-2	5	7	9
2-3	7	6	5
3-4	7	7	6
4-5	9	8	13
5-6	9	8	13
6-7	6	8	4
7-8	6	7	4
8-9	5	3	2
9-10	5	3	1
10-11	1	2	
11-12	1	1	

[a] Separate diurnal distributions were analyzed for three classes of gasoline stations: (1) small, below 200,000 gal/yr throughput, (2) medium, between 200,000 and 500,000 gal/yr throughput, and (3) large, above 500,000 gal/yr throughput. Data are based on 1,133 gasoline stations in the Tampa Bay area.

that particular hour in the detailed photochemical modeling inventory.

The hourly operating information in Table 6-5 is an example of the case where a special survey has been made to determine diurnal operating patterns. This approach is preferable, where resources allow, for the more important area source emitters. For many especially smaller sources, however, engineering judgment can provide sufficiently accurate temporal factors. For example, for off-highway fuel usage by farm and construction equipment, it is probably adequate to assume that the bulk of all emissions on weekdays occurs uniformly from 7 a.m. to 7 p.m.

The development of hourly area source emission estimates from annual emissions requires a great deal of repetitive data handling, and should generally be computerized. Area source data handling is discussed in more detail in Chapter 8.

6.4 AREA SOURCE PROJECTION PROCEDURES

As in apportioning area source emissions, two approaches can be used for making growth projections of area source emissions. The more accurate approach involves projecting the activity levels themselves. The more common approach, however, involves the use of growth indicators to approximate the increase or decrease of each activity level.

The first of the above-mentioned approaches is generally employed when a local survey has been made or local estimates are available projecting growth in specific areas. For example, if a survey of drycleaners has been performed and the average estimated growth in the modeling area is 5 percent per year, then in 5 years, drycleaning activity would be projected to increase by 28 percent*. As another example, a local asphalt trade association may be able to project cutback asphalt usage. When considering such estimates, the inventorying agency must recognize the possibility of deliberate or inadvertent biases due to wishful thinking or self-serving motives, and should strive to obtain opinions which are as objective as possible. Moreover, the agency should be careful to determine whether or not such estimates of future activity levels reflect the effects of anticipated control measures. This is important, as some such estimates may be more appropriately used in control strategy projections than in the baseline inventory. Most importantly, any such projections should be consistent with projections made by other planning agencies.

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*$(1.05)^5 = 1.28$, or a 28 percent increase

A common alternative to directly projecting activity levels is to use indicators of growth. A surrogate indicator concept was discussed in Section 6.2 with respect to spatially allocating area source emissions. In the context of projections, a surrogate growth indicator is one whose growth in the future is fairly certain and is assumed to behave similarly to the activity level of interest. The most commonly used surrogate growth indicators are those parameters typically projected by local MPO's, such as population, housing, land use, and employment. As one example, the quantity of miscellaneous solvent use in a projection year might be assumed to grow proportionally with population. Hence, if population increased in an area by 10 percent from the base year to the projection year, miscellaneous solvent usage would be assumed to increase by 10 percent, as well. Regardless of what variables are used as growth surrogates, the basic calculation is the same: the ratio of the value of the growth indicator in the projection year to its value in the base year is multiplied by the area source activity level in the base year to yield the projection year activity level.

A major difference between making area source projections for the basic, countywide inventory and for the detailed, photochemical inventory is that, in the latter, emission estimates must be resolved at the grid cell level. This adds a dimension of complexity to the projection effort as changing growth patterns may require that different apportioning factors be determined for the projection years. Fortunately, in most large urban areas where photochemical models are employed, the local MPO will be able to provide land use maps as well as detailed zonal projections of employment, population, etc., for future years. Hence, these projections can be used directly, as described above, to determine changes in spatial emission patterns.

If the surrogate indicators used for apportioning certain area source emissions are not projected at a subcounty level, engineering judgment must be used to decide whether spatial distributions of various activities will change enough to warrant the effort of identifying new patterns. Changes may be warranted in rapidly growing areas for the more important area source emitters. For regions where little growth is expected, and especially for minor area sources, the same apportioning factors can be used in baseline and projection inventories without incurring appreciable error.

In special cases, temporal factors and VOC split factors may also change in the projection years. Temporal factors may change as lifestyles and working patterns change, or as a result of governmental policy. For example, if a 4-day workweek is expected in a projection year, daily emission patterns from sources such as small degreasing operations may be altered. Or if gasoline sales are prohibited on certain days or during certain hours, daily emission patterns may change. Generally, however, temporal patterns for most area sources would not be expected to change, and hence, the same daily and hourly apportioning factors would be used in the baseline and projection years. VOC split factors are discussed in Chapter 7.

When making area source emission projections, control measures will have to be considered for certain source categories. The effect of controls on area sources can generally be indicated by changes either in emission factors or in activity levels, depending on the source and the nature of the control measure being considered. As an example, RACT for gasoline service stations could be accounted for by using an emission factor lower than the uncontrolled factor given in AP-42.[3,4] As another example, RACT for cutback asphalt paving could be evaluated simply by reducing the activity level in proportion to the fraction of cutback asphalt that would be replaced with emulsified asphalt.[5]

As with point sources, the area source projections should be carefully reviewed by the inventorying agency in light of all of the points (e.g., objectivity, openness, etc.) discussed in Section 2.6. It is especially important with respect to area sources that consistent methodologies be utilized for the base year and the projection years to estimate and apportion emissions for each source. For example, if emissions from gasoline evaporation at service stations in a base year are estimated and distributed as a result of a special study (e.g., questionnaires to individual service stations), it would be inconsistent to estimate such emissions for a future year based on projected VMT and to apportion these emissions based on the number of miles of road within each grid. Such inconsistencies will likely lead to changes in emissions that are not due to growth or control measures but, rather, to changes in the inventory procedures themselves.

A test to determine whether different base and projection year methodologies are mutually consistent is to apply the projection year methodology to the base year case and see if the results are identical. If important discrepancies are found, then one methodology should be chosen to apply to both years. Generally, any methodology which applies growth factors to base year estimates to estimate projection year emissions (or activity levels) will meet this consistency criterion.

6.5 SPECIFIC AREA SOURCE DATA

As discussed in preceding sections of this chapter, the detailed photochemical modeling inventory differs from the basic emissions inventory in the increased spatial and temporal resolution required. These additional considerations apply in the base year as well as in projection years.

Table 6-6 summarizes some approaches that have been employed for incorporating spatial and temporal resolution for area source categories in the detailed emissions inventory and for making projections of countywide emissions from area sources in future years. Surrogate indicators of area source activity are suggested for resolving emissions to the grid cell level. Temporal resolution procedures are illustrated by examples based on engineering judgment and emissions inventory experience[1]. Projection methodology is indicated in terms of suggested surrogate indicators of growth (which are sometimes the same as the suggested surrogate indicators of area source activity).

The information presented in Table 6-6 is not exhaustive, nor are the approaches suggested automatically applicable to all cases. Local information, if sound, is generally to be preferred. In various urban areas, the MPO's will have developed entirely different sets of surrogate indicators, both for spatial disaggregation and for projections; in some cases, substantially different methodologies may have been developed. For temporal resolution, local working hours and seasonal activity patterns may differ from those suggested here; some simpler suggestions are provided in the later sections of this chapter. The most general default option, in the absence of knowledge about temporal resolution, is the assumption of complete temporal uniformity. However, it is usually easy to determine whether any important emitting activity takes place mainly in the summer (as opposed to the winter), on weekdays (as opposed to

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES

(For interpretation of land-use codes see Table 6-1)

1. Aircraft, Commercial

Spatial Resolution

Surrogate indicator: airport area by airport (code 14)

Information source(s): land use map, local airport authority, and References 6, 7

Temporal Resolution

Seasonal:
Daily:
Hourly:
Since the temporal profiles of commercial airports vary widely, the respective airport managers should be contacted. The airport managers usually have very detailed temporal information.

Projections

Growth indicator(s): projections should be done on a case-by-case basis. Projected land use maps may be useful.

Information source(s): local airport authority, local MPO, state aviation system plan

2. Aircraft, General

Spatial Resolution

Surrogate indicator: airport area by airport (code 14)

Information source(s): land use map, local airport authority, and Reference 8

Temporal Resolution

Seasonal: uniform through the year

Daily: 40 percent of operations occur on weekends and 60 percent on weekdays.

Hourly: uniform from 0700 to 2100, otherwise zero

Projections

Growth indicator(s): projections should be done on a case-by-case basis; projected land use maps may be useful.

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

Information source(s): local airport authority, local MPO, state aviation system plan

Comments: the local airport managers should be contacted for this information.

3. Aircraft, Military

Spatial Resolution

Surrogate indicator: airport area by airport (code 14)
Information source(s): land use map, local airport authority, and Reference 9

Temporal Resolution

Seasonal:
Daily:
Hourly:
Projections
Growth indicator(s):
Information source(s):

estimate on individual basis - contact local airport authorities and appropriate military agencies

4. Agricultural Equipment

Spatial Resolution

Surrogate indicator: agricultural land (codes 21, 22, 24, 25, 28, and 29)
Information source(s): land use map and Reference 10

Temporal Resolution

Seasonal: uniform through the agricultural season
Daily: uniform through the week
Hourly: uniform from 0700 to 1900, otherwise zero

Projections[a]

Growth indicator(s): agricultural land use; agricultural employment
Information source(s): local MPO

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[a] Disparate trends for gasoline-fueled and diesel equipment suggest use of separate subcategories in these projections. See text.

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

5. Construction Equipment

Spatial Resolution

Surrogate indicator: built-up land and transitional areas (codes 16, 17, and 76)
Information source(s): land use map and Reference 11

Temporal Resolution

Seasonal[a]: 20 percent Dec-Feb, 25 percent Mar-May, 30 percent Jun-Aug, 25 percent Sep-Nov
Daily: Monday through Saturday
Hourly: uniform from 0700 to 1900 Monday through Friday and uniform from 0700 to 1200 on Saturday

Projections[b]

Growth indicator(s): heavy construction employment (SIC code 16)
Information source(s): local MPO

[a] National average. Refer to Reference 11 for further details.
[b] Disparate trends for gasoline-fueled and diesel equipment suggest use of separate subcategories in these projections. See text.

6. Industrial Equipment

Spatial Resolution

Surrogate indicator: industrial areas (codes 13 and 15)
Information source(s): land use map and Reference 12

Temporal Resolution

Seasonal[a]: 20 percent Dec-Feb, 25 percent Mar-May, 30 percent Jun-Aug, 25 percent Sep-Nov
Daily: uniform Monday through Saturday
Hourly: 80 percent from 0700 to 1900 and 20 percent from 1900 to 2400

Projections

Growth indicator(s): industrial employment (SIC codes 10-14, 20-39, and 50-51) or industrial land use area

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

Information Source(s): local MPO

[a] National average. Refer to Reference 12 for further details.

7. Lawn and Garden Equipment

Spatial Resolution

Surrogate indicator: residential areas (codes 10, 11, 16, and 17)
Information source(s): land use map and Reference 12

Temporal Resolution

Seasonal: uniform during months which have an average temperature of 38°F or higher
Daily: 50 percent Monday through Friday; 50 percent Saturday and Sunday
Hourly: uniform from 0900 to 1900, otherwise zero

Projections

Growth indicator(s) : single-unit housing or population [a]
Information source(s): local MPO

[a] Population may be taken as a growth indicator if it is assumed that average housing densities will remain constant.

8. Off-Highway Motorcycles

Spatial Resolution

Surrogate indicator[a]: open areas (codes 24, 31, 32, 33, and 73)
Information source(s) : land use map from local MPO; References 13, 14

Temporal Resolution

Seasonal: uniform during months which have an average temperature of 38°F or higher
Daily: 30 percent Monday through Friday, 70 percent Saturday and Sunday
Hourly: uniform from 0700 to 1800, otherwise zero

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

Projections

Growth indicator(s) : population
Information source(s): local MPO

[a]Take into account local restrictions on off-highway motorcycles.

9. Snowmobiles

Spatial Resolution

Surrogate indicator: areas where local restrictions allow their usage
Information source(s): land use map from local MPO

Temporal Resolution

Seasonal[a]: 63 percent Dec-Feb, 18 percent Mar-May, 0 percent Jun-Aug, 19 percent Sep-Nov
Daily: 30 percent Monday through Friday; 70 percent Saturday and Sunday
Hourly: uniform from 0700 to 1800, otherwise zero

Projections

Surrogate indicator(s): projected county population
Information source(s): local MPO

[a]National average. Refer to Reference 12 for further details.

10. Railroads

Spatial Resolution

Surrogate indicator: track mileage[a]
Information source(s): USGS transportation maps, Reference 15

Temporal Resolution

Seasonal: uniform through the year
Daily: uniform through the week
Hourly: 70 percent from 0700 to 1800 and 30 percent from 1800 to 0700

Projections

Growth indicator(s): revenue ton-miles

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

Information source(s): References 16, 17

[a] Assume emissions originate uniformly over all track miles, except that track mileage should be doubled in counties having significant rail yard operations.

11. Vessels, Ocean-Going and River Cargo Vessels

Spatial Resolution[a]

Surrogate indicator:	Ports for hoteling, shipping lanes for underway
Information source(s):	Waterborne Commerce of the U.S. and available maps, local port authorities

Temporal Resolution

Seasonal:	uniform through the year
Daily:	uniform through the week
Hourly:	75 percent from 0700 to 1900 and 25 percent from 1900 to 0700

Projections

Growth indicator(s):	cargo tonnage
Information source(s):	local port authorities, U.S. Maritime Administration, or the U.S. Army Corps of Engineers

[a] Ports and shipping lanes are identified in the Waterborne Commerce of the U.S. (Reference 18). Generally, ocean-going emissions are computed by port and by shipping lane. Separate subcategories may be used for ports versus shipping lanes.

12. Vessels, Small Pleasure Craft

Spatial Resolution

Surrogate indicator[a]:	assumed usage areas
Information source(s):	available maps and Reference 18

Temporal Resolution

Seasonal: uniform during the months which have an average temperature of 45°F or higher

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

Daily: 30 percent Monday through Friday, 70 percent Saturday and Sunday
Hourly: uniform from 0700 to 1800, otherwise zero

Projections

Growth indicator(s) : population
Information source(s): local MPO

[a] Assume that small craft utilize inland water areas (taking into account local restrictions) and waters 1 mile out from ocean-exposed shores uniformly

13. Gasoline Handling

Spatial Resolution

Surrogate indicator : Industrial and commercial-institutional land use areas
Information source(s): land use map and Reference 19

Temporal Resolution

Seasonal: uniform through the year
Daily: Monday through Saturday
Hourly: uniform from 0600 to 2000, otherwise zero

Projections

Growth indicator(s): gasoline demand, vehicle use (VMT), or population
Information source(s): U.S. Department of Transportation, state transportation agency, state tax agency, or local MPO, and Reference 20

14. Drycleaning

Spatial Resolution

Surrogate indicator: commercial areas (codes 12 and 15)
Retail service employment
Information source(s): land use map

Temporal Resolution

Seasonal: uniform
Daily: uniform Monday through Saturday
Hourly: uniform 0700-1900

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

Projections

Growth indicator: population, retail service employment
Information sources: solvent suppliers, trade associations

15. Degreasing

Spatial Resolution

Surrogate indicator: industrial area (codes 13 and 15)
Information source: land use map and Reference 21

Temporal Resolution

Seasonal: uniform
Daily: uniform Monday through Saturday
Hourly: 80 percent from 0700 to 1900, 20 percent from 1900 to 2400

Projections

Growth indicators: industrial employment
Information source: trade associations

16. Non-Industrial Surface Coatings

Spatial Resolution

Surrogate indicator: urban or built-up land (codes 10 through 17)
Information source(s): land use map

Temporal Resolution

Seasonal: uniform through the year
Daily: uniform through the week
Hourly: uniform 0700 to 1900, otherwise zero

Projections

Growth indicator(s): population or residential dwelling units
Information source(s): local MPO

17. Cutback Asphalt

Spatial Resolution

Surrogate indicator: urban or built-up land, (codes 10 through 17)
Information source(s): land use map

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

Temporal Resolution

Seasonal: uniform spring through fall
Daily: Monday through Friday
Hourly: uniform from 0700 to 1900, otherwise zero

Projections

Growth indicator(s): consult industry
Information source(s): consult industry

18. Pesticides Applications

Spatial Resolution

Surrogate indicator: agricultural land (codes 23-29)
Information source(s): land use map

Temporal Resolution

Seasonal: coincides with growing season
Daily: uniform through the week
Hourly: daylight hours, 0700 to 1900

Projections

Growth indicator(s): agricultural operations
Information source(s): State Department of Agriculture, MPO

19. Fuel Combustion, Residential

Spatial Resolution

Surrogate indicator: residential areas (codes 10, 11, 16, and 17); dwelling units
Information source(s): land use map

Temporal Resolution

Seasonal: 10 percent uniform through the year and 90 percent uniform during months which have an average temperature of 68°F or less
Daily: uniform through the week
Hourly: uniform through the day

Projections

Growth indicator(s): residential housing units or population
Information source(s): local MPO and Reference 22

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

20. Fuel Combustion, Commercial/Institutional

Spatial Resolution

Surrogate indicator: commercial areas (codes 12 and 15
Information source(s): land use map and Reference 23

Temporal Resolution

Seasonal: 25 percent uniform through the year and 75 percent uniform during months which have an average temperature of 68°F or less
Daily: 95 percent Monday through Saturday and 5 percent Sunday
Hourly: 90 percent from 0600 to 2400 and 10 percent from 2400 to 0600

Projections

Growth indicator(s): commercial/institutional employment, population, or commercial/institutional land use area
Information source(s): local MPO, land use map projections

21. Fuel Combustion, Industrial

Spatial Resolution

Surrogate indicator: industrial areas (codes 13 and 15)
Information source(s): land use map

Temporal Resolution

Seasonal: uniform through the year
Daily: uniform Monday through Saturday
Hourly: 80 percent from 0700 to 1800 and 20 percent from 1800 to 2400, otherwise zero

Projections

Growth indicator(s): industrial employment (SIC codes 10-14, 20-39, and 50-51) or industrial land use area
Information source(s): local MPO, land use projections

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Continued)

22. Solid Waste Disposal, On-Site Incineration and Open Burning

Spatial Resolution

Surrogate indicator: residential areas (codes 10,11, 16 and 17) commercial/institutional areas (codes 12 and 15) industrial areas (codes 13 and 15)

Information source(s): land use map

Temporal Resolution

Seasonal:
Daily:
Hourly:
base on information gathered from local regulatory agencies

Projections

Growth indicator(s):
Information source(s):
base on information gathered from local regulatory agencies

23. Fires: Managed Burning, Agricultural Field Burning, and Frost Control (Orchard Heaters)

Spatial Resolution

Surrogate indicator: areas where these activities occur

Information source(s): U.S. Forest Service, state forestry departments, state agricultural department, extension services, citrus grove operators, and land use map

Temporal Resolution

Seasonal:
Daily:
Hourly:
base on local regulations and on data collected from information sources

Projections

Growth indicator(s):
Information source(s):
base on anticipated local regulations as indicated by information sources.

24. Fires: Forest Wildfires and Structural Fires

Emissions from these two categories are not customarily input to models. Refer to the text for discussion.

Table 6-6. EXAMPLE METHODOLOGIES FOR SPATIAL AND TEMPORAL RESOLUTION AND PROJECTION OF COUNTYWIDE EMISSION TOTALS FOR AREA SOURCE CATEGORIES (Concluded)

25. Miscellaneous Solvent Use

Spatial Resolution

Surrogate indicator: residential, commercial/institutional areas (codes 12, 13, 15)
Information source(s): land use map

Temporal Resolution

Seasonal: uniform through the year
Daily: uniform
Hourly: 80 percent from 0700 to 1900, 20 percent from 1900 to 2400

Projections

Growth indicator(s): population
Information source(s): local MPO

weekends), or in the daytime (rather than at night). When such information is available, it should be utilized, especially if important emission categories are involved.

The approaches listed in Table 6-6 have been tested in practice, however, and are believed to be relatively plausible and feasible. The surrogate indicators are coded with reference to Tampa Bay area land use categories, shown in Table 6-1 and Figure 6-1. Similar maps are available for most urban areas, although not always with the same degree of detail.

It should, of course, be remembered that the only emissions to be disaggregated by these procedures are area source totals. If some of the sources in any category have been listed and treated as either major or minor point sources, the emissions from those sources must be subtracted from the countywide category total before the disaggregation procedure is applied. If local information is available that allows a major fraction of the emissions to be treated as minor point sources for both the base year and the projection years, such handling may be advantageous. However, if the number of such sources is minor and their aggregate emissions are inconsequential, or if the necessary projection information is inadequate, this subdivision of the area source category may not be worth the additional effort required.

The following sections in this chapter provide additional discussion of the material summarized in Table 6-6 for several area source categories.

6.6 AIRCRAFT

6.6.1 DATA COLLECTION

If aircraft emissions are a relatively large proportion of total VOC, it is advisable in the detailed inventory to obtain LTO data specific to the major airports of interest. The procedures that can be used to estimate VOC emissions from aircraft are summarized in Section 5.1.2 of Volume I of this report.

AP-42 gives emission factors for each mode of aircraft operation and representative time that the aircraft spends in each mode.[1] However, the times spent in the preflight and postflight taxi-idle modes are highly variable at most airports and may be considerably less than the times indicated in AP-42, which represent large, congested airports. More accurate values for the taxi-idle times should be obtained from local airport officials.

Also, the AP-42 times assumed in the approach and climbout modes are based on the times required to descend from and ascend to 3,500 ft (1,067 m), which may not be a representative height for the airport being considered. For example, if the emission data are being prepared for a model simulation run of a particular day for which there was a low inversion base of 1,000 ft (305 m), the estimate based on a 3,500 ft (1,067 m) height would overestimate the actual emissions that would impact the mixing layer, because emissions occurring in the stable layer above the inversion base would become trapped aloft and so would have no impact on the concentrations in the mixing layer or at ground level. Climbouts and approaches are made at fairly uniform rates, so the times given in

AP-42 can be adjusted accordingly if the 3,500 ft (1,067 m) value has to be revised. A photochemical modeling specialist should be consulted prior to making any such adjustment to determine what conditions should be assumed in the inventory.

6.6.2 SPATIAL RESOLUTION

When the modeling grid system has been drawn on a map which shows the location of the airports, it will be apparent how to assign the airport emissions to the individual grid cells: taxiing and idling occur between the runways and the terminal buildings or hangars; takeoffs and landings take place along the runways; and climbouts and approaches should be assigned to the areas that extend beyond the ends of the runways. Many airports are large enough to require several grid cells for emission distribution. If only total airport emissions are known, they can be distributed by the fraction of airport area in each grid cell.

6.6.3 TEMPORAL RESOLUTION

Most airports keep detailed records of daily flight activity. The diurnal activity patterns should be obtained by specific inquiry for the individual airports in the modeling area.

6.6.4 PROJECTIONS

Estimates of aircraft emissions in future years require assumptions regarding the following factors:

1. Future airport locations
2. Distribution of operations by type of aircraft
3. Rates of emission by type of aircraft during landing and takeoff operations

Information about possible plans affecting these factors can usually be obtained from local airport directors, airport authorities, State Departments of Transportation, and the Federal Aviation Administration. For military airports and air bases, officials of each relevant service should be consulted.

6.7 OTHER OFF-HIGHWAY FUEL USAGE

6.7.1 DATA COLLECTION

Other off-highway fuel usage includes motorcycles, farm equipment, construction equipment, industrial equipment, and lawn and garden equipment. Emission estimation techniques for these categories are described in Section 5.1.5 of Volume I.

6.7.2 SPATIAL RESOLUTION

Since these VOC sources are relatively minor, the grid cell allocation techniques are not critical. If possible, off-highway motorcycle emissions should be allocated to park or recreational areas, construction and industrial equipment emissions to industrial areas, farm equipment emissions to agricultural areas, and lawn and garden equipment emissions to residential areas.

6.7.3 TEMPORAL RESOLUTION

For all off-highway sources, it is probably adequate to assume that 75 percent of the emissions occur uniformly from 7 a.m. to 7 p.m., with 25 percent occurring uniformly over the remaining 12 hours. Some more detailed suggestions, however, are shown in Table 6-6.

Seasonal variations estimated by Southwest Research Institute (References 11 and 12) indicate that off-highway fuel usage is about 20 percent greater in the summer than on the annual average.

6.7.4 PROJECTIONS

When locale-specific growth data are not available, the following trend indicators can be used: (Reference 1)

1. For off-highway motorcycles, population
2. For lawn and garden equipment, single-family housing
3. For agricultural equipment, farm acreage
4. For industrial equipment, industrial employment
5. For heavy construction equipment, construction employment

6.8 RAILROADS

6.8.1 SPATIAL RESOLUTION

The best method of apportioning railroad emissions to individual grid cells is to obtain suitable maps of railroad track mileage (including detailed maps of switchyards) from railroad companies or state and local planning agencies, and to determine manually the track mileage in each grid cell. The total county or regional emissions can then be apportioned by the fraction of total track mileage in each grid cell.

6.8.2 TEMPORAL RESOLUTION

Seasonal and diurnal activity curves can be obtained by specific inquiry of the individual railroad companies operating in the modeling area.

6.8.3 PROJECTIONS

The Association of American Railroads (Reference 17) has recently constructed three scenarios for national railroad industry growth, which may be consulted as a point of reference for estimating trends in railroad emissions. Locale-specific growth data should be utilized first, of course, if available.

6.9 VESSELS

6.9.1 SPATIAL RESOLUTION

In order to determine to which grid cells the emissions from vessels should be assigned, it is necessary to obtain detailed maps of the harbors, shipping lanes, and recreational areas in the study area. These shipping and boating areas can then be used as a surrogate indicator for allocating the countywide vessel emissions to the appropriate grid cells.

6.9.2 TEMPORAL RESOLUTION

Vessels contribute relatively minor amounts of emissions to the urban total; diurnal patterns can be obtained by specific inquiry for any major sources within this group. For combined smaller sources, it is probably adequate to assume that 75 percent of the emissions occur uniformly between 6 a.m. and 6 p.m., with 25 percent occurring uniformly over the remaining 12 hours.

6.9.3 PROJECTIONS

Estimates of emissions from vessels in future years require assumptions regarding the following factors:

1. Future development or expansion of harbor facilities
2. Trends in volume of shipping into harbors
3. Changes in distribution of types and drafts of vessels entering harbors and using waterways
4. Trends in recreational boat usage

Sources of information for projection scenarios include various port authorities and Federal agencies, including the U.S. Coast Guard, Interstate Commerce Commission, and the U.S. Department of the Army Corps of Engineers. Where Naval activity appears to be an important factor, the appropriate U.S. Naval District should be consulted.

6.10 GASOLINE SERVICE STATIONS

6.10.1 SPATIAL RESOLUTION

If a local survey has been made which yields the amount of gasoline handled by each station, emissions can be directly computed for each station and assigned to the appropriate grid cell. If only countywide service station emissions are known, emissions may be apportioned based on the amount of residential and commercial land use in each grid cell.

6.10.2 TEMPORAL RESOLUTION

Gasoline station evaporation losses may, with little error, be taken to be proportional to throughput. The diurnal variation of throughput from gasoline stations in Tampa Bay was studied in some detail and tables were derived for stations in three categories, based on rate of throughput. Table 6-5 shows the results.[1] These data suggest that little error would be involved in assuming a uniform distribution of gasoline sales from 6 a.m. to 8 p.m.

6.10.3 PROJECTIONS

Since gasoline handling is, in many areas, an important area source of VOC emissions, it is desirable to apply a detailed methodology in forecasting gasoline usage and projecting emissions. Federal, state, and local transportation agencies may be able to provide official forecasts of VMT, and state and Federal energy agencies are likely to have information relating to gasoline supply and average miles-per-gallon fuel use estimates. If this information is not available locally, national gasoline demand may be the best growth indicator; however, if the population of the area is expected to grow at a rate significantly different from the growth rate in national population, an adjustment should be made to take this into account. This may be done for example, by the following formula:

$$G_j = G_o \times \left(1 + \frac{R_n}{100} \frac{r_c}{r_n}\right)^j$$

where

G_j is gasoline demand in the projection year,

j is the number of years from the base year to the projection year,

G_o is the gasoline demand in the base year,

R_n is the average annual rate of increase of national gasoline demand, in percent,

r_c is the average annual rate of increase of the county (or regional) population, and

r_n is the average annual rate of increase of the national population.

A simple projection of recent countywide trends may give misleading results if chronic gasoline supply problems develop in future years. Even in the absence of such problems, the effects of rising prices on gasoline demand may cause substantial deviations from recent trends in both gasoline consumption and in vehicle miles traveled (VMT). Another factor which can complicate the projection problem is the increasing mileage rating of light-duty vehicles; if VMT is to be used as a surrogate indicator of growth in gasoline consumption, an adjustment which reflects this increase will be needed.

Projected emissions for gasoline handling must also incorporate factors for the reduction of emissions due to imposed control measures. A reduction of 95 percent in emissions generated during delivery of gasoline to service stations ("Stage I loading") has already been mandated by the EPA requirements for implementation of reasonably available control technology (RACT).[3] A reduction in emissions generated during delivery of gasoline to individual customers at the service stations ("Stage II loading") will be similarly mandated when the CTG document for Stage II loading, expected in the near future, is published.

6.11 DRYCLEANING

6.11.1 SPATIAL RESOLUTION

Countywide drycleaning emissions should be apportioned to commercial areas or to employment in retail services, after emissions from plants identified as point sources have been subtracted.

6.11.2 TEMPORAL RESOLUTION

Drycleaning emissions may be assumed to be emitted during daylight hours, unless more specific information is available locally regarding the diurnal distribution of drycleaning activity. Operating hours for small plants may differ from those for plants large enough to be considered as point sources.

6.11.3 PROJECTIONS

Future drycleaning activity may be assumed to grow in proportion to population, or to employment in retail services. Trends in usage of different solvents for drycleaning may differ; trade association sources should be consulted for information about such shifts. Control techniques for solvent evaporation from drycleaning where the solvent used is perchlorethylene are described in a recently issued CTG document, Reference 24.

6.12 DEGREASING

6.12.1 SPATIAL RESOLUTION

Countywide degreasing emissions should be apportioned to industrial areas or to employment in appropriate industries, after degreasing emissions from point sources have been subtracted. In the application of LIRAQ to the San Francisco Bay Area, 98 percent of degreasing emissions were found to come from area sources.[2] Degreasing emissions were ascribed to four employment categories, as described in Section 6.2.2.2.

6.12.2 TEMPORAL RESOLUTION

Degreasing emissions may be assumed to be correlated with industrial activity in general and to occur mainly during daylight hours, unless more specific local information is available.

6.12.3 PROJECTIONS

Future activity in degreasing may be assumed to grow in proportion to area-source industrial activity generally, or in proportion to employment in the aggregate of employment categories used in apportioning the degreasing emissions to planning zones and grid squares. Again, employment in major point sources should be deleted from the statistics before the area-source growth rates are computed. Trends in usage of different solvents for degreasing may differ; trade association sources should be consulted for information about such shifts. Control techniques for solvent evaporation from metal degreasing are discussed in a CTG document, Reference 25.

6.13 NONINDUSTRIAL SURFACE COATING

6.13.1 SPATIAL RESOLUTION

Surface coating emissions from public use of trade paints should be apportioned to residential, industrial, and commercial/institutional areas of the land use map, or to appropriate demographic parameters. In the application of LIRAQ to the San Francisco Bay Area, 64 percent of nonindustrial surface coating emissions were attributed to dwelling units and 3 percent to each of 12 employment categories, as indicated in Table 6-3.[2]

6.13.2 TEMPORAL RESOLUTION

Seasonal variation is likely to be pronounced, especially for architectural surface coating, in areas having severe winter conditions. Trade paints are likely to be used most when the weather is warm; thus, emissions from this source will be relatively more important in the oxidant season than at other times of the year.

Surface coating emissions from area sources may be assumed uniform during daylight hours.

6.13.3 PROJECTIONS

Suitable growth indicators for activity in nonindustrial surface coating are population and residential dwelling units. Trade association sources should be consulted regarding trends in VOC content of the trade paints in future years. Control techniques for VOC evaporation from architectural and miscellaneous coating materials are to be discussed in an EPA CTG document to be issued in the near future.

6.14 CUTBACK ASPHALT

6.14.1 SPATIAL RESOLUTION

Emissions by solvent evaporation from the use of cutback asphalt, mainly in paving, should be apportioned to residential and commercial areas.

6.14.2 TEMPORAL RESOLUTION

Cutback asphalt use is likely to be subject to substantial seasonal variation, especially in areas where severe winters may interfere with paving operations. Thus, emissions from this source will, in many places, be relatively more important during the oxidant season than at other times of the year.

Since evaporation of the diluent may continue for days or weeks after a cutback asphalt paving operation is completed, it is probably sufficiently accurate to assume a uniform distribution of emissions from this source during daylight hours.

6.14.3 PROJECTIONS

According to the CTG document for cutback asphalt use, VOC emissions from this source will be eliminated by the use of an emulsified asphalt containing no VOC diluent.[5] Implementation of this regulation is expected to be complete by 1982. Therefore, for 1982 and subsequent years the total VOC emissions from this source may be taken as zero.

6.15 PESTICIDES APPLICATIONS

6.15.1 SPATIAL RESOLUTION

Application of pesticides occurs mainly on agriculturally zoned land, but also (to some extent) on range and forest land. Local and state agricultural and forestry agencies may be able to supply more specific information regarding locations where pesticides are routinely applied.

6.15.2 TEMPORAL RESOLUTION

Seasonal variation in emissions due to pesticides applications is likely to be pronounced, as the operation occurs mainly during the growing season.

This activity is ordinarily restricted to daylight hours.

6.15.3 PROJECTIONS

Future activity in pesticides applications may be assumed to grow (or decline) in proportion to agricultural acreage or agricultural employment. Trends in VOC components of applied pesticides may be superposed on these activity trends. State agricultural agencies may be able to furnish relevant information.

6.16 FUEL COMBUSTION

6.16.1 SPATIAL RESOLUTION

The separate area source emissions from residential, commercial, and industrial fuel combustion should be allocated to individual grid cells using the corresponding land use areas as surrogate indicators.

6.16.2 TEMPORAL RESOLUTION

Area source fuel combustion contributes relatively minor amounts of VOC and NO_x emissions to the urban total. Further, most of the fuel used for space heating is burned in the cold months, when weather is not conducive to oxidant formation. Only that industrial fuel use not associated with space heating will occur during the summer season. Suggestions regarding temporal resolution of these emissions are included in categories 13, 14, and 15 of Table 6-6.

6.16.3 PROJECTIONS

Since VOC and NO_x emissions from fuel combustion area sources are commonly low, there is little need for complexity in developing projection estimates for these sources. The principal factor to be accounted for in projections is the change in industrial, commercial, and residential fuel demand, which may be estimated with the assistance of State or local planning officials. Major anticipated changes in the land use map may also be factored into the projection scenarios.

6.17 OTHER MISCELLANEOUS AREA SOURCES

6.17.1 DATA COLLECTION

Several minor categories of VOC emissions should be included in the inventory, namely solid waste disposal (onsite incineration and open burning), agricultural burning, and structural fires. Emission estimation techniques for solid waste disposal are given in Section 5.3 of Volume I; techniques for estimating emissions from agricultural burning, structural fires, and other miscellaneous area sources appear in Section 5.5 of that document. Existing countywide estimates for these sources will normally be sufficient for use in the detailed inventory. Since agricultural burning and structural fires are intermittent sources, there is a possibility that they should be excluded if the inventory is to represent a typical day. This should be decided during the inventory strategy planning.

6.17.2 SPATIAL RESOLUTION

In most cases the detailed information necessary to accurately assign the emissions to individual grid cells is not available, so the apportioning can be performed only in a general manner. Onsite incineration emissions should be allocated evenly to residential, commercial, and industrial areas; open burning emissions should be allocated to rural areas; agricultural burning should be allocated to agricultural areas; and structural fires should be distributed evenly over residential, commercial, and industrial areas.

6.17.3 TEMPORAL RESOLUTION

Agricultural burning is a seasonal activity in which all emissions are released during a short period of the year. Local air pollution control agencies should be contacted to determine the normal daily duration of such burning. For other miscellaneous area sources, it is probably adequate to assume that 75 percent of the emissions occur uniformly from 6 a.m. to 6 p.m., with 25 percent occurring uniformly over the remaining 12 hours.

6.17.4 PROJECTIONS

Local air pollution control agencies and solid waste collection agencies should be contacted to determine future regulations applicable to on-site incineration and open burning. In many locations, open burning may be prohibited by law in the future, and incineration will probably require controls. For structural fires, emission estimation by population growth is an adequate projection technique.

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7.0 VOC (AND NO_x) ALLOCATION INTO CHEMICAL CLASSES

As discussed in Section 2.6 of Chapter 2.0, most photochemical models require information about VOC composition in terms of designated groups or "classes" of compounds. Additionally, in some models, NO_x may have to be specified as NO and NO_2. Each model's classification requirements differ somewhat; hence, the following discussion is necessarily somewhat general in describing how VOC and NO_x are allocated into classes. More specific details on currently available models are included in Appendix A.

7.1 ALLOCATION OF VOC TO CLASSES

Generally, the basic annual inventory will contain estimates of either total VOC or nonmethane VOC, depending on what emission factor information is used for computing emissions. The basic approach for allocating VOC into the classes needed by a photochemical model is to employ a set of "split factors" that distribute a certain fraction of the VOC total into each class.

A simple example demonstrates the concept: assume a source emits 10 tons of VOC per day, and that the photochemical model being employed requires VOC emissions to be divided into three classes. Given split factors for this particular source of 0.2, 0.5, and 0.3, simple multiplication of each factor by total VOC yields the quantity of VOC in each class, in this case 2, 5, and 3 tons per day. These three totals, for instance, could represent the quantities of paraffins, olefins, and aromatics, respectively, composing the total VOC emissions from the particular source.* If another photochemical model is used that requires six reactive classes, the mechanics of performing the allocation would be the same except that six split factors would be needed rather than three. This allocation step would, of course, have to be performed for each emission total developed in the inventory using different split factors appropriate for each source or source category.

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*It should be noted that the "reactive classes", as designated by the model designers, do not always coincide with the chemical classes implied by their assigned names. For instance, aldehydes do not fit, chemically, into any of the classes named above, but, as VOC's, they must be allocated to one or another of these classes, to fulfill the requirements of the model. It should also be

As can be seen from the above example, the VOC allocation step is not difficult once the split factors are available for each source. The major difficulty in this process is determining what split factors are most appropriate. Two basic approaches can be followed for determining split factors. Ideally, VOC split factors should be source specific. For example, because of the importance of gasoline evaporation in VOC inventories, local gasoline composition data should be obtained corresponding to the summer season in the modeling area. Additionally, source tests could be performed to determine VOC species data for each refinery, chemical manufacturer, etc., and solvent composition data could be solicited from each drycleaner, degreaser, etc. From this information, a photochemical modeling specialist could determine appropriate split factors for each source.

Generally, however, with the exception of a few very large point or area source emitters, it will not be practical for an agency to collect such information, due to resource limitations and because many facilities will not be able or willing to supply solvent composition data. Hence, in most cases, the agency will have to utilize generalized VOC species data from the literature in order to develop model-specific VOC split factors. An example of the kind of species data developed for a particular source category--automotive exhaust--is shown in Table 7-1.* A photochemical

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noted that photochemical models generally require mole rather than weight quantities of each class. Hence, as is described later in this chapter, a weight-to-mole conversion step is also required during this allocation process.

*Table 7-1 shows, for the sake of example, the estimated composition of composite exhaust gases from gasoline-fueled vehicles for a vehicle mix characteristic of the State of California in a recent year, using fuels available at that time. This sort of

Table 7-1. ESTIMATED COMPOSITION OF EXHAUST GASES FROM HIGHWAY AND OFF-HIGHWAY VEHICLES GASOLINE FUEL, COMPOSITE OF ALL GRADES[a]

Line No.	SAROAD Code		Molecular Weight	Percent Weight	Percent Volume	Chemical Classification
1	43212	N-Butane	58.12	2.90	2.19	1 Paraffin
2	43220	N-Pentane	72.15	6.90	4.20	1 Paraffin
3	43231	N-Hexane	86.17	2.50	1.27	1 Paraffin
4	43232	N-Heptane	100.20	3.00	1.31	1 Paraffin
5	43233	N-Octane	114.23	12.30	4.72	1 Paraffin
6	43235	N-Nonane	128.25	1.00	.35	1 Paraffin
7	43203	Ethylene	28.05	11.40	17.75	2 Olefin
8	43205	Propylene	42.08	7.30	7.61	2 Olefin
9	43213	Butene	56.10	4.40	3.41	2 Olefin
10	43224	1-Pentene	70.13	2.80	1.75	2 Olefin
11	43245	1-Hexene	84.16	2.10	1.09	2 Olefin
12	45102	Isomers of Xylene	106.16	4.00	1.66	3 Aromatic
13	45105	Isomers of Butylbenzene	134.21	.10	.04	3 Aromatic
14	45107	Isomers of Trimethylbenzene	120.19	2.10	.79	3 Aromatic
15	45202	Toluene	92.13	10.90	5.16	3 Aromatic
16	45203	Ethylbenzene	106.16	.80	.35	3 Aromatic
17	43502	Formaldehyde	30.03	3.90	5.68	4 Carbonyl
18	43206	Acetylene	26.04	8.70	14.60	5 Miscellaneous
19	43201	Methane	16.04	8.40	22.91	6 Methane
20	43202	Ethane	30.07	.70	1.01	7 Nonreactive
21	45201	Benzene	78.11	3.80	2.14	7 Nonreactive
		TOTAL		100.00	99.99	
		6 Compounds of Classification 1	89.39	28.60	14.04	
		5 Compounds of Classification 2	38.72	28.00	31.61	
		5 Compounds of Classification 3	98.64	17.90	8.00	
		1 Compound of Classification 4	30.03	3.90	5.68	
		1 Compound of Classification 5	26.04	8.70	14.60	
		1 Compound of Classification 6	16.04	8.40	22.91	
		2 Compounds of Classification 7	62.71	4.50	3.15	
		21 Compound Composite	43.84	100.00	99.99	

[a] Refer to Reference 1

modeling specialist can utilize this type of data, in conjunction with a knowledge of the model's reactivity requirements, to allocate organic compounds from each source category to the correct VOC classes, and thus develop split factors tailored to any model.

An example of "lumping" species into classes is also demonstrated in Table 7-1. In the 7-class scheme shown at the bottom of this table, paraffins are lumped together as one class (chemical classification 1), olefins as class 2, aromatics as class 3, etc. The weight and volume percentages associated with each organic compound are summed for each classification and average molecular weights computed. The resulting composite percentages after division by 100 represent the split factors that can be used for allocating emissions of this particular gas into this particular 7-class scheme. Both weight and volume percentages are shown in Table 7-1, but for any specific model, only one set or the other will actually be needed, depending on whether the model requires emissions information in terms of the mass or number of moles of VOC classes. An example of the general split factors utilized in the San Francisco Bay Area's LIRAQ model, which uses a 3-class scheme, is shown in Table 7-2 (Reference 2).

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table is obtained by combining compositions of exhaust samples from numerous individual automobiles, each weighted to represent a part of the spectrum of vehicles actually in use in the state. Similar estimates can be made for other years and other locations, given the necessary information as to the vehicle mix.

Table 7-1 is taken from the VOC Species Data Manual, published by EPA in December 1978 (refer to Reference 1). This manual provides "emission profiles" like the example in Table 7-1 for 175 unique point and area stationary sources, as well as composite profiles for mobile sources, giving for each a list of individual VOC species with corresponding percentages, and a composition summary in terms of seven VOC classes. Where no specific local information exists, the profiles given in the manual may be useful. However, for major point sources and important area sources, locally applicable information should always be sought.

Table 7-2. EXAMPLE VOC ALLOCATION FACTORS BY SOURCE CATEGORY FOR A 3-CLASS SCHEME[a]

Source Type	HC_1 (%)	HC_2 (%)	HC_4 (%)
Petroleum production	-	100	-
Refinery operations	23	77	-
Underground storage	15	85	-
Auto filling tanks	27	73	-
Fuel consumption	38	30	32
Waste burning fires	22	40	38
Heat treated coatings	20	80	-
Air dried coatings	14.4	85	0.6
Drycleaning-petroleum based	2	98	-
Drycleaning-synthetic	-	100	-
Degreasing-trichloroethylene	100	-	-
Degreasing-1,1,1-trichloroethane	-	100	-
Rotogravure printing	7	93	-
Flexigraphic printing	21	78	1
Rubber, plastics, etc. mfg.	36	51.5	12.5
Pharmaceuticals	27	70	3
Misc. solvents	17	80	3
Gasoline exhaust	22	71	7
Gasoline evaporation (mobile)	24	76	-
Diesel exhaust	18	60	22
Gas turbine (jet)	33	53	14
Piston aircraft	26	66	8

[a] As used in LIRAQ Model (Refer to Reference 2). Note that in LIRAQ, in addition to the above split factors, each category is adjusted by an additional factor (not shown) to account for varying reactivities associated with each particular species mix.

The so-called "carbon bond" mechanism, which is an option in the Urban Airshed Model, requires an additional step beyond the determination of split factors for VOC classes; the user must also subdivide the VOC classes into fractions which will be assumed to react in different ways in the mechanism's reaction set. Alternatively, if the composition of the VOC emissions is given in terms of individual compounds, each of these individual species will be divided up into the corresponding fractions before entry into the chemical reaction system of the model.

If the agency intends to employ a model that incorporates the carbon bond mechanism, a photochemical modeling specialist should be consulted to review all procedures, algorithms, and VOC species/split factor data prior to initiating any data collection or allocation effort, and for advice on how to deal with other types of VOC's. Indeed, such expertise should be engaged in this process regardless of what model is applied or what approach is used to allocate VOC into reactive classes. In no case should the agency develop split factors or carry out such an allocation without knowing what photochemical model will be run or what classification scheme is needed to meet the model's reactivity requirements.

7.2 SPECIFICATION OF NO_x AS NO AND NO_2

As indicated in the description of various photochemical models given in Appendix A, some models do not require that nitrogen oxides be distinguished as either nitric oxide or nitrogen dioxide. Instead, these models assume that all NO_x is NO, which is the predominant form of NO_x emitted from all combustion processes.

For those models that do require this split to be made, split factors are applied in the same manner as are VOC split factors. That is, for each source or source category emitting NO_x, two percentages (totaling 100 percent) need to be defined: one corresponding to the fraction of NO_x emitted as NO and the other corresponding to the fraction emitted as NO_2. In this sense, allocating NO_x into NO and NO_2 is analogous to utilizing a 2-class scheme for allocating VOC.

The mode of expression of the necessary split factors may vary from one model to another. NO_x emissions are ordinarily expressed "as NO_2", which means that a molecular weight of 46 is attributed to NO as well as NO_2, even though the true molecular weight of NO is 30. Many models take account of this convention by accepting split factors totaling 100 percent for NO_x "as NO_2", but some may require NO emissions to be expressed in terms of the true weight of NO. The true value for NO is 30/46 or 0.65 times the conventional value of NO "as NO_2".

If the inventory maintains NO totals as NO, then care should be taken that a molecular weight of 30 is used when computing moles of NO for use in the photochemical model. It is important, during the planning stages, to review the annual inventory to determine how NO_x is reported and to consult with a modeling specialist to find out how the photochemical model accepts NO_x emissions data.

As an example of NO_x allocation, consider a power plant that emits NO_x equivalent to 1,000 kg of NO_2 per hour. Given split factors of 95 and 5 percent by weight "as NO_2", then NO and NO_2 emissions would be equivalent to 950 and 50 kg "as NO_2" per hour, respectively; however, the actual emissions of NO would be only 30/46 of 950, or 620 kg per hour.

At present, few references are available that define split factors for allocating NO_x into NO and NO_2. Reference 3 yields such data for many types of stationary combustion sources. As a rough average, 97 percent (by weight as NO_2) of the NO_x emitted from most boilers will be NO (as NO_2).

7.3 PROJECTING VOC (AND NO_x) SPLIT FACTORS

Just as the quantity of emissions may change in an area from the base year to any projection year, the composition of these emissions may change, as well. To reflect this, the VOC and NO_x split factors used in the model may need changing in each projection year, at least for important sources for which such a change can be estimated. One source for which this may be an important consideration is motor vehicles. With an increasing fraction of the vehicle mix expected to consist of catalyst-equipped cars, whose emissions contain a higher percentage of methane and light paraffins than uncontrolled cars, significantly different VOC split factors may be appropriate in projection years. Similarly, if significant changes are expected in the compositions of petroleum products transported and stored in the modeling area, such changes should be reflected in the projection year split factors, as well. Of course, for many sources, no changes in emission composition will be expected. For instance, no change would be needed for any sources that will use the same solvents in the base year and projection years (e.g., drycleaners using perchloroethylene). Likewise, since no evidence suggests that NO/NO_2 ratios in combustion emissions will change in the near future, the same NO_x split factors could also be used in projection years.

In no case should different split factors be used in any projection inventory unless they reflect anticipated changes in the composition of future emissions. Any other changes may cause the photochemical model to predict changes in ozone concentrations that are due simply to differences in methodology and are unrelated to expected real effects of composition changes.

7.4 COMPATIBILITY WITH INVENTORY DATA AND SOURCE CATEGORIES

An important consideration when allocating VOC into classes is one that may be easily overlooked. Split factors must be given in terms compatible with those used to express VOC totals in the basic inventory. Ordinarily, this means that they should be given as fractions of total VOC, including methane and any other organic compounds considered unreactive, if such compounds are present in the emissions for the category under consideration. However, if the basic inventory has been compiled in terms of nonmethane hydrocarbons (NMHC) or reactive volatile organic compounds (RVOC), the split factors should be given as fractions of these totals rather than of total VOC.

For example, the split factors shown in Table 7-1 are immediately applicable to total emissions given as total VOC (including methane). If they were to be applied (erroneously) to total NMHC emissions estimates, the resulting emission estimates in each VOC class would be underestimated, since a smaller total would have been allocated.

In this case, the given split factors would have to be adjusted to make them applicable to nonmethane VOC emissions. This can be readily accomplished by dividing each of the weight (or volume) percentages corresponding to each chemical classification by the quantity [(1 - percent methane/100)] where "percent methane" is the weight (or volume) percent corresponding to classification 6. As an example of this, referring to Table 7-1, the existing weight percent associated with classification 1 in motor vehicle exhaust is 28.6. To convert this to a split factor that would be applicable to a nonmethane emission weight total, it would be divided by the fraction of nonmethane VOC, namely 1-(8.7/100) (since 8.7 is the weight percentage of methane, classification 6) to yield 31.3, then by 100 to convert percentage to a fraction, 0.313. The other split factors would be adjusted accordingly. The sum of all the converted nonmethane split factors should be 1.0 if these conversions have been performed correctly.

If the existing inventory is not in terms of total VOC or total nonmethane VOC, and instead is divided into some sort of classification scheme that is incompatible with the scheme needed by the photochemical model, it is questionable whether such an inventory will be useful as input to the photochemical model. A photochemical modeling specialist should be consulted if this situation exists.

As suggested in Section 2.5 of Chapter 2.0, another important issue is split factor-source classification compatibility. It may often happen that the source categories and subcategories chosen for the basic inventory fail to distinguish between sources having substantially different emission compositions, which therefore require different sets of split factors. For example, area source degreasing may be considered as a single category, but different degreasing solvents may be used in different plants. There are several possible solutions to this problem.

First, any individual plants which emit significant amounts of solvent vapors from degreasing operations can be treated as point sources, in which case the solvents used at each should be identified and entered in the point source inventory.

Second, if there are many degreasing operations, each of which emits only relatively small amounts of solvent vapors, it may be possible to determine from solvent suppliers how much of each solvent is used in the region. Lacking any information to the contrary, the agency may then assume that the emissions of each solvent are uniformly spread through the industrial areas of the region. In this case degreasing can be treated as a single area source category, with split factors in proportion to the overall supply; or, alternatively, it can be subdivided into several area source categories, one for each solvent, with the emission totals as determined from the suppliers.

Third, if there is no locally available information, state or national supply statistics can be used to provide estimates of the split factors or the subcategory totals, to be used in the manner previously explained.

A similar situation may be encountered in dealing with motor vehicle emissions; split factors may be known for exhaust and evaporative VOC's separately, whereas the basic inventory may only provide a single lumped estimate combining these two emission components. Since this source is a very important one in most urban areas, it is best to recalculate these emissions in terms of the two subcategories, then apply the appropriate split factors to each category. This enhances the accuracy of the VOC allocation process and facilitates the use of the model to evaluate control strategies that may affect exhaust and evaporative emissions differently.

There will also be cases in which compositional information is simply not available in sufficient detail to permit determination of split factors for many recognized VOC sources. For instance, a petroleum refinery may be represented in the inventory by a large number of point sources (having, for example, different NEDS source classification codes) while only a single set of split factors is available for the entire point source category (as, for example, in Table 7-2).

For less significant VOC sources, such as area source fuel combustion, there is correspondingly less need for accuracy in assigning split factors, since moderate errors in these small contributions will result in only very small errors in the individual VOC class totals. A single set of split factors is, therefore, adequate for all external combustion sources operating on a given type of fuel, and no subcategories would be necessary or useful in this case.

In general, it is important to review the source category list at an early stage of the planning to ensure that all subcategories essential for proper allocation of emissions to VOC classes have been recognized and established for data collection. This is especially important if special surveys or questionnaires are to be utilized, because failure to retrieve all the necessary information in the initial contact can seriously impair the productivity of the effort.

References for Chapter 7.0

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8.0 DATA HANDLING

8.1 GENERAL

The basic distinction between the annual inventory and the detailed inventory used for photochemical modeling is that, in the latter, a greater degree of temporal and spatial resolution is needed and VOC (and NOx) have to be apportioned to classes. The preceding chapters in this document have largely centered on the conceptual aspects of incorporating this additional resolution into the annual emission inventory. Up to this point, however, nothing has been said concerning how this conversion is best accomplished from a data management standpoint. Obviously, since many repetitive data manipulations are required to complete the photochemical modeling inventory in a large urban area, a detailed consideration of data handling is appropriate prior to initiating the inventory effort. This chapter focuses on the primary data handling activities needed in the detailed inventory effort, and discusses how each data handling step can be facilitated. Because the data handling considerations are quite different for point, area, and highway vehicle sources, a separate discussion is included for each in subsequent paragraphs.

It should be noted that although most data handling will typically be computerized to the extent possible, some steps will nevertheless still have to be performed manually. This distinction will be emphasized in the following discussion for those data handling steps that are better carried out either one way or the other.

The final product of the detailed inventory effort is the modeler's tape used as input to the photochemical model. A separate modeler's tape must be prepared for each base year and projection scenario that is to be evaluated. A brief discussion of a generalized modeler's tape format is included in this chapter.

8.2 POINT SOURCE DATA HANDLING

When assigning point source emissions to specific grid cells, either a manual or computerized approach can be utilized. Generally, unless there are very few point sources in the modeling area, a computerized assignment is more practical. In this approach, a program is written that compares the UTM (or other) coordinates stored in each point source record with the coordinates of the grid cells and determines in which specific grid cell the point is located. The appropriate grid cell identifier (or coordinates) can either be written on the point source record (if space is available) or else a separate correspondence file can be created containing this data. Subsequently, any time a modeler's tape is generated, this point-to-grid-cell correspondence information can be accessed to assign point source emissions to grid cells. It would be possible to generate the point-to-grid-cell correspondence data during the creation of the modeler's tape; however, this alternative would have the disadvantage of requiring the coordinate comparison step to be repeated for every modeler's tape created.

As mentioned in Section 4.2, the point-to-grid-cell assignment step can also be performed manually by overlaying an outline of the grid system onto a map showing the point source locations. If this is done, the resulting correspondence data will still have to be loaded onto either the point source records or a machine-readable correspondence file, as described previously, in order to be utilized by the program that creates the modeler's tape. The manual approach, as mentioned previously, has the disadvantage of being much more time-consuming if numerous point source assignments are necessary.

Some photochemical models do not require that elevated point sources be assigned to grid cells. In these models, preprocessor programs are available that make this assignment based on the point source coordinates available from the annual, countywide inventory. If this is the case, point-to-grid-cell correspondences need not be determined for these particular sources. Generally, however, since the modelers may not know in advance which sources will be considered as elevated, and since computerized assignments will be practiced in most instances, little extra effort will be expended in simply making this assignment for all point sources. Thus, this information will always be available in case it is needed at a later date.

Hour-by-hour point source emissions are estimated by applying seasonal, daily, and hourly operating factors to the annual emissions. This concept was discussed in Chapter 4. In the data handling system, the temporal factors and the resulting hourly emissions can be stored either in the individual point source records (if space is available) or on a separate file created for this purpose. A potential disadvantage of storing hourly emissions on each point source record is that a great deal of file space is required. An alternative is to have the program that creates the modeler's tape compute hourly emissions at the point source level but simply accumulate hourly emissions at the grid cell level. If this alternative is employed, VOC and NO_x splits would have to be applied to each point prior to accumulation at the grid cell level in order not to lose the pollutant split identity of each source category. A disadvantage of this latter approach is that hourly emissions and pollutant splits must be recomputed each time a modeler's tape is created. An example of a file containing point source temporal factors for calculating hourly emissions from annual emissions is shown in Table 8-1. The entries for such a file have to be determined manually using the procedures outlined in Chapter 4. Different temporal patterns can be simulated (e.g., in projection inventories) by simply changing the factors in this file to reflect anticipated operating rate changes.

Table 8-1. EXAMPLE TEMPORAL FACTOR FILE FOR INDIVIDUAL POINT SOURCES (EXCERPT)

SCC[a]	Source Pt[b]	Temporal Factors[c]						Code[d]
30200000	02			27.0				S
30200000	02	1.43						D
30200000	02	2.29	2.29	2.29	2.29	2.29	2.29	1H
30200000	02	2.78	3.21	3.92	4.58	5.23	5.23	2H
30200000	02	5.23	5.23	5.23	5.23	5.23	5.23	3H
30200000	02	5.23	5.23	5.23	5.23	5.23	3.76	4H
30200000	03			32.0				S
30200000	03	1.76						D
30200000	03	2.99	2.99	2.99	2.99	2.99	2.99	1H
30200000	03	2.99	3.63	4.28	4.28	4.28	5.00	2H
30200000	03	5.77	5.77	5.77	5.77	5.77	5.00	3H
30200000	03	4.28	4.28	4.28	4.28	3.63	2.99	4H

[a] Plant identification by SCC code (eight digits).

[b] Point source identification by number within plant. (Note that state, county and plant ID's are not shown and should be included for complete identification.) Six successive lines constitute one point source record.

[c] Definitions: Seasonal, percentage of annual activity occurring during chosen quarter-year; daily, percentage of seasonal activity occurring on selected day; hourly, percentage of daily activity occurring on selected hour. Six consecutive hourly values appear on one line.

[d] Code: S, seasonal; D, daily; 1H, hourly, 0001 to 0600. 2H, 0601 to 1200. 3H, 1201 to 1800. 4H, 1801 to 2400.

The allocation of VOC (and NO_X) into classes is similar to the allocation of annual emissions into hourly increments. Basically, as is conceptually described in Chapter 4, the VOC (and NO_X) emissions from each point source are multiplied by "split factors" to allocate them into classes. A separate file of split factors can be created for this purpose, an example of which is shown in Table 8-2, or the split factors can be stored as part of the point source records. Molecular weights should be stored similarly.

It should be noted that the file shown in Table 8-2 gives split factors by source category (i.e., at the SCC level) and not for each point source. This approach is generally recommended, since (1) specific split factors will not be known for most individual facilities, and (2) considerably less file space will be needed. A disadvantage of this approach is that it makes it difficult to reflect specific split factor information that may be available for individual operations.

As in calculating hourly emissions, estimates of VOC (and NOx) by class can either be (1) computed prior to the generation of the modeler's tape and stored in the point source records or in a separate file, or (2) computed during the creation of the modeler's tape, to conserve file space. A disadvantage of the latter approach is that VOC (and NOx) emissions by class have to be recomputed each time a modeler's tape is created. In any projection inventory, new VOC (and NOx) split factors can be reflected simply by changing the split factor files and applying them to the projected VOC (and NOx) emission totals.

Of course, if the model being used employs carbon bond chemistry, special algorithms generally will have to be executed subsequent to applying VOC split factors. These algorithms are fairly simple; hence, no special data handling problems should be encountered in incorporating them into the VOC allocation routine.

Table 8-2. EXAMPLE "SPLIT FACTOR" FILE (EXCERPT)

Source Category[a] SCC	Pollutant Code[b]	Class 1[c]		Class 2[c]		Class 3[c]		Class4[c]	
		SF[d]	MW[e]	SF	MW	SF	MW	SF	MW
30600801[f]	HC	34.5	46	56.9	61	7.9	71	.7	96
30600802	HC	13.8	46	75.0	81	3.9	72	7.3	92
30600803	HC	5.0	52	84.0	87	6.6	72	4.4	96
40300106	HC	13.9	58	73.5	61	11.2	72	1.4	92
40300107	HC	13.9	58	73.5	61	11.2	72	1.4	92
40300152	HC	1.1	38	57.3	68	37.0	31	4.6	101
40300205	HC	1.1	38	57.3	68	37.0	31	4.6	101
30000606	NX	85.0	30	15.0	46				
30000608	NX	85.0	30	15.0	46				

[a] Source category by SCC code (eight digits).

[b] Code: HC, VOC; NX, NOx.

[c] Classes are defined as follows:
for VOC, class 1 is nonreactives; class 2, paraffins;
class 3, olefins; class 4, aromatics
for NOx, class 1 is NO; class 2, NO_2

[d] Split factor, percent of total, by weight.

[e] Average molecular weight.

[f] Each line constitutes a record, either for VOC or for NOx, for one source category.

8.3 AREA SOURCE DATA HANDLING

The major difference between area source data handling and point source data handling concerns the way emissions are estimated at the grid cell level. Since point source locations are typically known to the nearest tenth of a kilometer, it is easy to assign them to specific grid cells. Area source emissions, however, are typically only resolved to the county (or equivalent) level in annual inventories and, thus, must be disaggregated to the grid cell level using apportioning procedures such as are described in Chapter 6.

Area source apportioning factors can be stored in a special file, an example excerpt of which is shown in Table 8-3. This file is basically a matrix of apportioning factor values by grid cell. In this table the surrogate indicators are designated along the top, and the grid coordinates are presented along the side. The values loaded into the table represent the fraction of the countywide total of each variable that is located within each particular grid cell. (Such a table would have to be prepared for each county equivalent level for which area source emissions are resolved in the annual inventory.) Hence, in order to determine emissions from a particular area source in a given grid cell, the calculation program (1) determines what surrogate indicator is appropriate for the source in question (this information would be written into or supplied to the emission calculation routine), (2) accesses the apportioning factor file to determine what fraction corresponds to the grid cell/surrogate indicator combination in question, and then (3) multiplies that fraction by the countywide emission total for the particular area source.

The sequence of steps described in the previous paragraph applies to inventories in which each area source category is apportioned by only one surrogate indicator. If an area source category is to be apportioned by multiple surrogate indicators, the same

Table 8-3. EXAMPLE FILE OF GRID CELL APPORTIONING FACTORS FOR AREA SOURCES (EXCERPT)

Grid Cell Coordinates[a]	Apportioning Factors for					
	SI1[b]	SI2[b]	SI3[b]	SI4[b]	SI5[b]	SI6[b]
272,784	.001	.001	.001	.0	.004	.0
274,784	.001	.001	.001	.0	.004	.0
276,784	.001	.001	.001	.0	.004	.0
278,784	.001	.001	.001	.0	.004	.0
280,784	.001	.001	.001	.0	.003	.0
252,786	.001	.002	.002	.0	.004	.0
254,786	.011	.011	.012	.0	.0	.045
256,786	.013	.014	.015	.0	.0	.270
258,786	.001	.001	.001	.0	.004	.009
260,786	.001	.001	.001	.100	.004	.0

[a] UTM coordinates of grid cell, SW corner, Km.

[b] Apportioning factors for this example are based on the following surrogate indicators: SI1, employment; SI2, commercial employment; SI3, dwelling units; SI4, general aviation; SI5, open burning; SI6, vehicle miles traveled.

The entry in each case is the fraction of the total indicated activity which occurs in the grid cell.

procedure can be followed by creating new subcategories corresponding to the level of activity to be apportioned by each indicator as discussed in Section 6.2.2.1.

Thus, referring again to the example given in Section 6.2.2.2, if area source degreasing emissions are 42 tons per day of VOC and these are estimated to arise 10 percent from MFG4 activities, 60 percent from MFG5 activities, 20 percent from retail service activities, and 10 percent from other service activities, the area source degreasing category can be partitioned into four subcategories, having respective totals of 4.2, 25.2, 8.4, and 4.2 tons per day. Each subcategory would then be apportioned to the grid cell level by its appropriate surrogate indicator as previously described. These subcategories would appear in the area source apportioning factor file, but not necessarily in the emissions inventory provided by the operating agency.

Where the agency chooses to allocate area source emissions based on zonal statistics on population, employment, etc., instead of using land use maps, a data handling procedure is necessary to convert the zonal level apportioning information to the grid cell level. As discussed in Section 6.2.2.2, the first steps in this process are to overlay a map showing the grid system boundaries over a map showing the zonal boundaries, and then determine or estimate fractions of zonal areas lying within specific grid cells. These areal fractions are then loaded into a machine-readable file to serve as zone-to-grid-cell correspondence values. This file, in turn, can be used to generate grid cell apportioning factors by (1) multiplying the surrogate indicator values available at the zonal level (e.g., from forecasting models) by the areal fractions for each zone, (2) summing over all zones, and (3) normalizing, as shown in the equations given in Section 6.2.2.2. The latter steps should be computerized because of the great amount of data handling involved when hundreds of zones and grid cells are involved.

The estimation of hourly area source emissions is accomplished using essentially the same data handling procedures as are described in Section 8.2 for point sources. Basically, a file of seasonal, daily, and hourly temporal factors is created (similar in format to Table 8-1) that can be multiplied by the annual area source emissions to generate hourly emission estimates. Typically, one set of temporal operating factors will be loaded into this file for each area source category, and will be applicable for the entire modeling area. The determination of the appropriate factors for the area source temporal factor file is a manual procedure, and is described in Section 6.3.

The allocation of area source VOC (and NOx) into classes is also similar to the allocation of point source emissions into classes. Generally, a file of area source split factors can be created for this purpose (similar to that shown in Table 8-2) or, alternately, these split factors can be stored in the area source records themselves if space is available. These split factors are simply multiplied by the VOC (and NOx) totals to estimate emissions by class. If a model employing carbon bond chemistry is employed, special algorithms may have to be applied subsequent to this step to estimate the number of moles of various carbon bonds.

In area source projection inventories, anticipated changes in land use patterns, temporal patterns, and VOC (and NOx) split factors can be readily accommodated by simply changing the values in all the above files and then applying them to the projected inventory of annual, countywide emissions. Any changes in these files would, of course, have to be manually determined for each projection year.

8.4 HIGHWAY VEHICLE DATA HANDLING

As described in Chapter 5, much of the development of the detailed photochemical inventory of highway vehicle emissions is accomplished using available DOT and EPA computer packages. Specifically, either the UTPS or PLANPAC/BACKPAC batteries will typically be employed for developing link/zone VMT estimates; HWYEMIS1, APRAC-2, or SAPOLLUT will be used as network emission models to calculate link/intrazonal VMT emissions; and MOBILE1 will be used to generate highway vehicle emission factors used in the network models. Because each of these computer packages is described in Chapter 5, and since complete user's documentation is available thereon, no additional discussion is included here. The reader should consult the references cited in Chapter 5 for data handling details on these available packages.

The transportation, emission factor, and network emission models described in Chapter 5 generally yield temporally resolved highway vehicle emission estimates at the link/zonal level. Current network models can also provide gridded emission estimates; however, this capability is of limited usefulness as considerably more spatial resolution is required in detailed photochemical inventories than these models provide. Hence, the agency responsible for the detailed highway vehicle inventory will have to develop link/zone-to-grid-cell conversion routines before creating the modeler's tape. Emissions for each link are apportioned to grid squares by assuming that the emissions are uniformly distributed along a straight line. The fraction of the link-segment that falls within a given grid square determines the fraction of the total emissions for that link that fall in that square. The contributions of all links are summed for each square. Zonal emissions are aggregated at the grid cell level by developing an equivalency table designating the fraction of each zone lying within each grid cell, and assigning emissions accordingly.

Another function not performed by the available FHWA/EPA transportation packages is the allocation of VOC (and NOx) emissions into classes. This step can be carried out similarly to the procedure described in Section 8.2, with separate split factors used for each vehicle category for which an emission total is carried along by the network emission calculation model. Ideally, as is done in some areas, VMT and emissions are calculated separately for each major vehicle type (e.g., LDV, HDV, etc.), in which case vehicle-type-specific VOC and NOx split factors can be applied. In other cases, however, network models may supply only composite emissions for all vehicles, in which case composite split factors will have to be applied based on the fraction of travel by each vehicle type.

When making the VOC and NOx splits for light-duty vehicles, it is also important to note whether the inventory distinguishes exhaust from evaporative emissions. Since the VOC compositions of the exhaust and evaporative components are significantly different, this distinction is desirable and should be maintained through the VOC allocation process. MOBILE1, as an option, classifies highway vehicle emissions into the exhaust and evaporative components.

8.5 MODELER'S TAPE CREATION

The final emission inventory product needed in data-intensive photochemical models is the modeler's tape. This is a file of hourly, gridded emissions for each pollutant (including VOC and NOx classes) that is formatted to interface with the photochemical model. As mentioned previously, separate modeler's tapes are needed for each inventory scenario that will be modeled.

Each photochemical model requires different input information for its modeler's tape and formats vary appreciably. In addition, some models have preprocessor programs that convert certain data items to model format. Also, less data-intensive models may accept daily rather than hourly gridded emissions, together with diurnal distributions as estimated for broad groups of categories. Because of the wide variety of models available, specific details of the input data and format requirements are beyond the scope of this document.

A generalized modeler's tape format is shown in Figures 8-1 and 8-2. Figure 8-1 shows a typical format for elevated point sources, while Figure 8-2 shows a ground level source format. The distinction between elevated and ground level sources is made in some models in order to incorporate some measure of vertical resolution. There are no hard-and-fast rules regarding what sources need to be considered as elevated sources on the modeler's tape. To some extent, this decision may be made by the photochemical modeler after reviewing point source data. Because a great amount of file space is required on the modeler's tape to store all of the information needed on elevated sources, it is generally desirable to include many of the smaller, low level point sources as ground level sources.

It should be noted that the ground level file on the modeler's tape combines low level point, area, and highway vehicle emissions for each hour and for each grid. Hence, the program that creates the modeler's tape must be capable of merging emissions from these three types of sources at the grid cell level. Elevated point sources may or may not have to be assigned to the grid cell level during the creation of the modeler's tape, depending on the model and depending on the availability of a preprocessor program that will make this assignment. In the example elevated source format shown in Figure 8-1, only the UTM coordinates for each point source are needed, which a preprocessor program subsequently uses to assign emissions to the proper grid cell. Model documentation should be consulted during the planning stages to determine what data are needed in the modeler's tape, in what format, and what steps are accomplished by the preprocessor program available with the model being used.

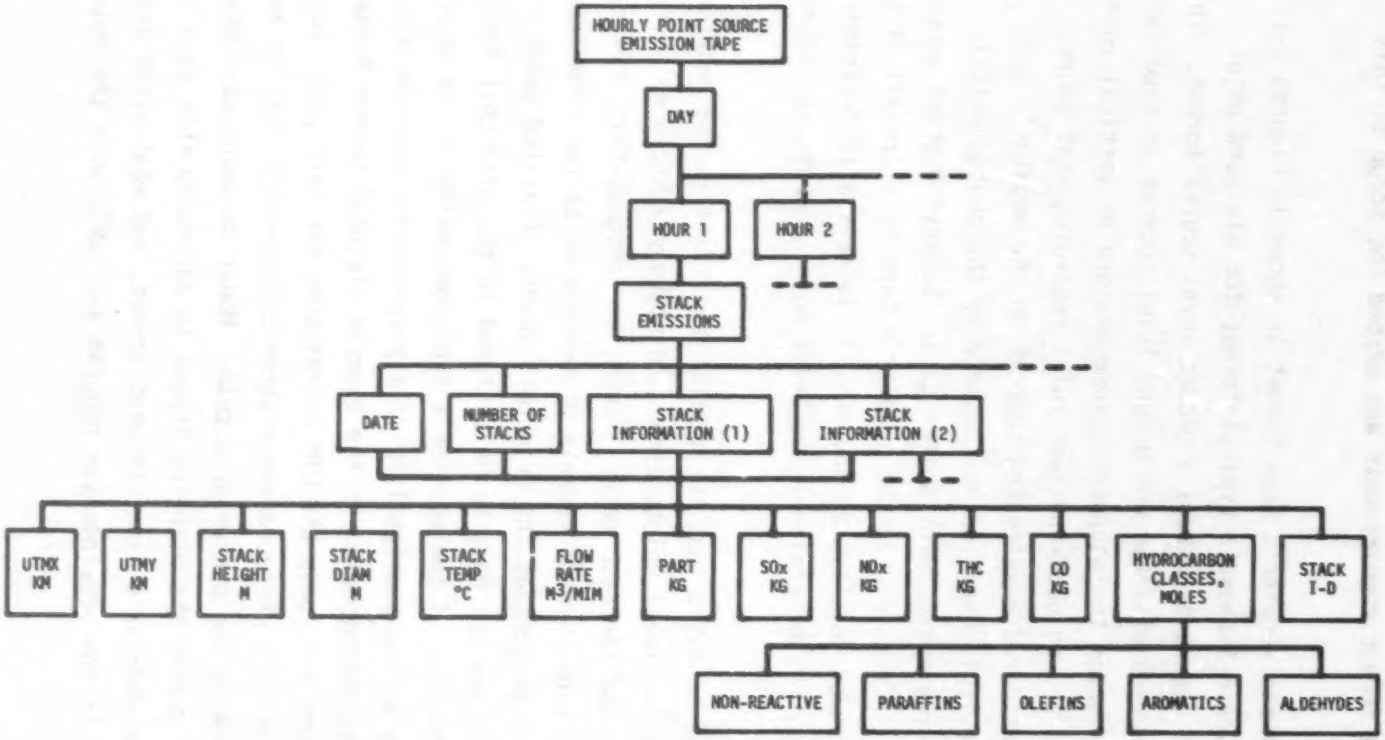
HOURLY POINT SOURCE EMISSION TAPE
DAY
HOUR 1
HOUR 2
STACK EMISSIONS
DATE
NUMBER OF STACKS
STACK INFORMATION (1)
STACK INFORMATION (2)
UTMX KM
UTMY KM
STACK HEIGHT M
STACK DIAM M
STACK TEMP °C
FLOW RATE M^3/MIM
PART KG
SOx KG
NOx KG
THC KG
CO KG
HYDROCARBON CLASSES, MOLES
STACK I-D
NON-REACTIVE
PARAFFINS
OLEFINS
AROMATICS
ALDEHYDES

Figure 8-1. Example of File Structure for Elevated Point Sources in Modelers Tape

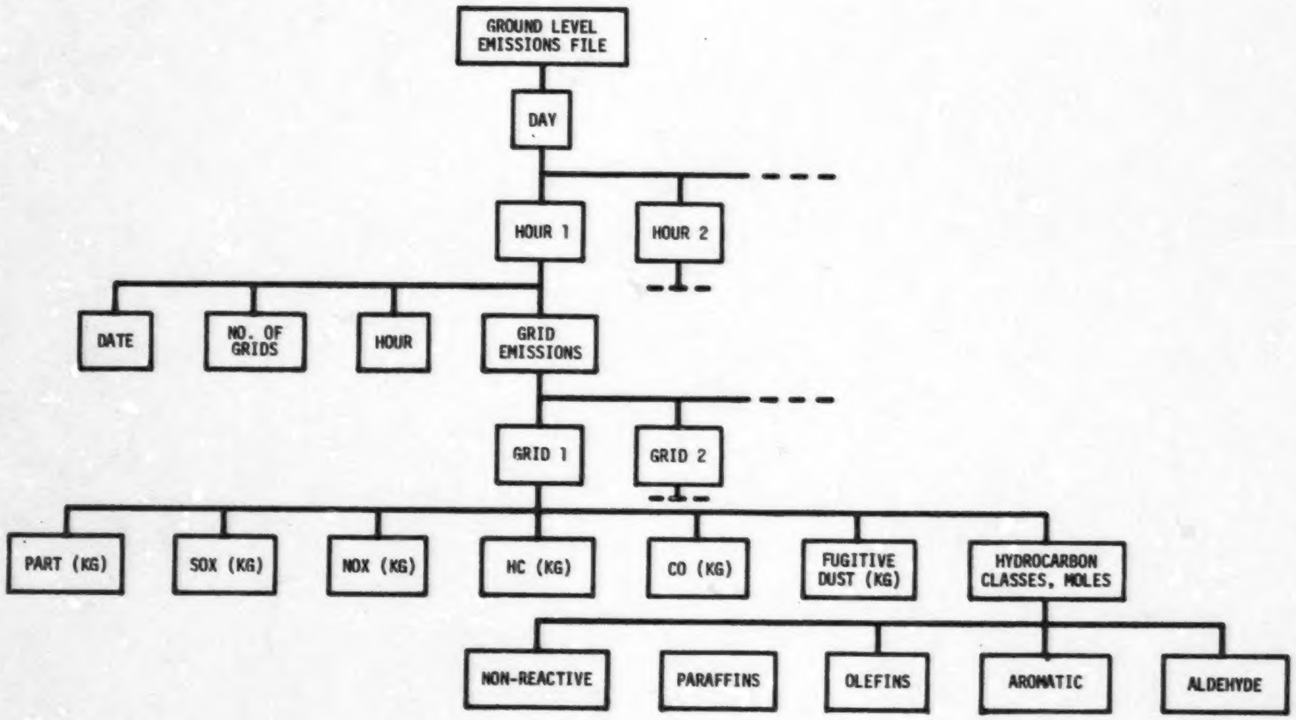
GROUND LEVEL EMISSIONS FILE
DAY
HOUR 1
HOUR 2
DATE
NO. OF GRIDS
HOUR
GRID EMISSIONS
GRID 1
GRID 2
PART (KG)
SOX (KG)
NOX (KG)
HC (KG)
CO (KG)
FUGITIVE DUST (KG)
HYDROCARBON CLASSES, MOLES
NON-REACTIVE
PARAFFINS
OLEFINS
AROMATIC
ALDEHYDE

Figure 8-2. Example of File Structure for Ground Level Emissions in Modelers Tape

APPENDIX A

URBAN SCALE PHOTOCHEMICAL
AIR QUALITY
SIMULATION MODELS

URBAN SCALE PHOTOCHEMICAL AIR QUALITY SIMULATION MODELS

Urban scale photochemical air quality simulation models are briefly discussed in the following pages. All of these models are or soon will be available for general use, either from the National Technical Information Service (NTIS), EPA, or the California Air Resources Board.

The models are characterized according to (1) the theoretical approach taken toward simulation of the atmospheric system; (2) the chemical reaction mechanism used to simulate the rates of appearance and disappearance of the reactive chemical species present in the atmosphere; and (3) the format provided for input of emissions information.

The theoretical approach is, basically, either Lagrangian or Eulerian. In the Lagrangian approach, computational complexity is reduced through decoupling of the chemical and fluid-dynamic aspects of the simulation; this is achieved by focusing attention on the chemical processes within individual moving air parcels. In the Eulerian approach, advantage is taken of the extensive capabilities of modern computer systems in order to simulate both chemical and fluid-dynamic aspects in all parts of the atmosphere simultaneously. Lagrangian models are often called "trajectory" models because of the requirement of identifying plausible trajectories for the air parcels which are to be simulated; Eulerian models are often called "grid" models, because the fluid-dynamic aspects are defined with respect to a gridded map covering the simulated region.

Chemical reaction mechanisms are defined in terms of a limited set of reactive chemical species which are presumed to be subject to a limited set of "elementary" chemical reactions. The species involved include ozone precursors, i.e., volatile organic compounds and oxides or nitrogen; secondary pollutants, including ozone, that are produced by the chemical reactions; and intermediate or "non-accumulating" species, such as free atoms of oxygen and free hydroxyl radicals, which on theoretical grounds are believed to be present, but at concentrations so low that ordinary chemical procedures do not detect them. The format for representation of the reactive VOC's is of particular importance to the user, since he will be required to apply different sets of "split factors" for use in different models, depending on the chemical species used in the models to simulate the reactive VOC's. The NOx format is equally important but less troublesome, as only two species are involved--nitric oxide (NO), and nitrogen dioxide (NO_2).

Gridded information on emissions is required for all photochemical air quality simulation models. To use a Lagrangian model in reference to a selected trajectory, emissions input is needed only for the area immediately surrounding the trajectory. However, for most practical applications, enough trajectories will be simulated so that almost all of the areas in the available emissions grid will be involved; therefore, it is preferable to provide the complete gridded emissions inventory at the outset. To use an Eulerian model, the complete gridded inventory must always be provided.

Diurnal emissions are represented, in the input to Eulerian models, by providing detailed hourly information for each grid cell and for each separately identified point source. For input to Lagrangian models, in some cases, diurnal variation may be simulated by estimated hourly distributions that apply to sources in particular categories, as described in the user's guides. In such cases, the gridded emissions input is usually formatted in terms of emissions for a 24-hour period.

The purpose of this appendix is to describe, briefly, the main features of currently available models. For further details, the user's guides provided with the models are usually adequate; however, the originating firms or organizations will often provide consultation with regard to particular problems that may be brought to their attention.

Model Designation: REM/TRACE

Developed by: Pacific Environmental Services, Inc.
1930 14th Street
Santa Monica, California 90404
(213) 450-1800

Model Description

REM and TRACE are trajectory models in which a single vertical cell is assumed to reach from ground level to the mixing height, with instantaneous mixing. The two models have different chemical reaction mechanisms. TRACE includes a module which simulates the effect of horizontal diffusion of pollutants out of the moving cell. Computer requirements are moderate.

Chemistry

REM contains a 34-reaction mechanism based on two classes of hydrocarbons; less reactive and more reactive (methane excluded).

TRACE contains a 76-reaction mechanism based on two classes of hydrocarbons, represented in terms of surrogate species, propylene and butane. Methane is excluded. This mechanism is the one used in EPA's Empirical Kinetic Modeling Approach (EKMA).

Emissions Source Categories

Both REM and TRACE accept emissions from categories labeled (1) freeways, (2) streets, (3) area sources. All emissions except those from motor vehicle traffic are included among the "area" sources. Emission from point sources are attributed to the grid square in which they originate, unless their effective stack height is greater than the mixing height (in which case they are deleted).

Emissions in each category are specified in terms of a daily total of non-methane hydrocarbon for each grid square and a diurnal distribution in terms of percent of the daily total emitted in each hour. For each grid square, the fraction of more reactive hydrocarbon in each category is also entered. NOx emissions are similarly entered in terms of daily totals and hourly percentage distributions; they are taken to be 100 percent NO. CO may also be entered, although it has little or no effect on the concentrations of photochemical pollutants.

All point sources are included in overall emissions for each grid square.

References:

1. L. G. Wayne, A. Kokin, M. I. Weisburd (1973) Controlled Evaluation of the Reactive Environmental Simulation Model (REM), Volume I: Final Report. Pacific Environmental Services, Inc., Santa Monica, California, EPA R4-73-013a, NTIS No. PB 220 456/8.
2. A. Kokin, L. G. Wayne, and M. I. Weisburd (1973) Controlled Evaluation of the Reactive Environmental Simulation Model (REM), Volume II: User's Guide. Pacific Environmental Services, Inc., Santa Monica, California, EPA No. R4-73-013b, NTIS No. PB 220 457/6.
3. P. J. Drivas and L. G. Wayne (1978) Sensitivity Tests of a Largrangian Photochemical Air Quality Simulation Model. Paper No. 78-10.3, APCA Annual Meeting, Houston, Texas.

Model Designation: DIFKIN/ELSTAR

Developed by: Environmental Research and Technology, Inc.
2625 Townsgate Road
Westlake Village, California 91360
(213) 889-5313

Model Description

DIFKIN and ELSTAR are trajectory models in which a columnar air parcel comprising one to five vertically stacked cells is assumed to reach from the ground level to the mixing height. The two models have different chemical reaction mechanisms, and ELSTAR includes algorithms to simulate the loss of pollutants at the ground. Computer requirements are moderate. (DIFKIN is now considered obsolete.)

Chemistry

DIFKIN contains a 16-reaction mechanism with one class of reactive hydrocarbon.

ELSTAR contains a 62-reaction mechanism with six VOC classes, designated as alkanes, ethylene, other alkenes, aromatics, formaldehyde, and other aldehydes.

Emission Source Categories

Both DIFKIN and ELSTAR accept emissions from categories labeled freeways, streets, and area sources. In addition, point sources are individually considered in ELSTAR. Diurnal distributions of hourly emissions are specifed for freeways, streets, power plants and refineries. NOx emissions are taken to be 90 percent NO. CO may also be entered, although it has little or no effect on the concentration of photochemical pollutants.

All point sources are included in overall emissions for each grid square.

References:

1. A. Q. Eschenroeder, J. R. Martinez, and R. A. Nordsieck (1972) Evaluation of a Diffusion Model for Photochemical Smog Simulation, Final Report. General Research Corporation, Santa Barbara, California, EPA No. R4-73-012a.

2. J. R. Martinez, (1972) User's Guide to Diffusion/Kinetics (DIFKIN) Code. General Research Corporation, Santa Barbara, California, EPA NO. R4-73-012b.

3. Lurman, F., D. Godden, A.C. Lloyd, R.A. Nordsieck (Oct. 1978). The Adaptation of a Lagrangian Photochemical Air Quality Simulation Model to the St. Louis Region and the Regional Air Pollution Study (RAPS) Data Base, Vols. I & II, Draft Report. EPA Contract No. 68-02-2765, Research Triangle Park, N.C.

Model Designation: MADCAP

Developed by: Form and Substance, Inc.
875 Westlake Blvd., Suite 212
Westlake Village, California 91361
(213) 889-0514

Model Description

MADCAP has been called a "hybrid" model, in that it simulates chemical reactions by Lagrangian principles while retaining an Eulerian framework for air flow. It allows for several layers of vertically stacked cells between ground level and mixing height. Computer requirements are rather extensive.

Chemistry

MADCAP contains a 58-reaction mechanism based on three VOC classes. These are designated HC1 (olefins and relatively reactive aromatics), HC2 (alkanes, naphthenes, less reactive aromatics and some oxygenates), and HC3 (aldehydes and certain ketones).

Emission Source Categories

Tabulated hourly emissions are entered for each cell of the Eulerian framework, including the elevated cells, which receive emissions from point sources with large enough effective stack heights. The emissions are tabulated in terms of the three VOC classes, NO, NO_2, and (optionally) CO.

Elevated Point Source Requirements

Effective stack height of point sources necessary to input hourly gridded emissions into elevated grid cells.

References:

1. R. C. Sklarew, J. C. Wilson, and A. J. Fabrick (1977) Verification of the MADCAP Model of Photochemical Air Pollution in the San Diego Air Basin. Form and Substance, Westlake Village, California, Technical Report 10-77-01.

2. R. J. Gelinas, and P. D. Skewes-Cox (1977) Tropospheric Photochemical Mechanisms. J. Phys. Chem., 81, 2468-2479.

Model Designation: LIRAQ

Developed by: Lawrence Livermore Laboratory
University of California
P. O. Box 808
Livermore, California 94550
(415) 422-1826

Model Description

LIRAQ is an Eulerian framework model having one layer of well-mixed vertical cells between ground level and the mixing height, with each cell corresponding to one emission grid square. Loss of pollutants at the ground can be accommodated. Computer requirements are very extensive.

Chemistry

LIRAQ contains a 56-reaction chemical mechanism based on three VOC classes. These are designated HC1 (alkenes and relatively reactive aromatics); HC2 (alkanes, less reactive aromatics and some oxygenates); and HC4 (aldehydes, some aromatics, and ketones). Methane is excluded.

Emission Source Categories

Tabulated hourly emissions are entered for categories known as (1) airport, (2) major-industrial, (3) population-dependent, and (4) vehicular. Pollutants entered are particulates, HC1, HC2, HC4, NO, SO_2, and CO. All NOx is assumed to be NO.

Elevated Point Source Requirements

Although the model has no vertical resolution, a distinction is made between surface and elevated emissions (higher than 100 ft); in the model, elevated emissions do not immediately impact their vertical grid cells.

References:

1. M. C. MacCracken, and G. D. Sauter (1975) Development of an Air Pollution Model for the San Francisco Bay Area, Final Report to the National Science Foundation. Lawrence Livermore Laboratory, Livermore, California, UCRL-51920, Volumes 1 and 2.

2. M. C. MacCracken (1975) User's Guide to the LIRAQ Model: An Air Pollution Model for the San Francisco Bay Area. Lawrence Livermore Laboratory, Livermore, California, UCRL-51983.

3. Livermore Regional Air Quality Model (LIRAQ) Application to St. Louis. Lawrence Livermore Laboratory, Livermore, California, UCRL-52432.

4. M.C. MacCracken, et al. (1978) The Livermore Regional Air Quality Model: I Concept and Development. J. Appl. Meteorol., 17, 264-272.

5. W.H. Deuwer, M.C. MacCracken, and J.J. Walton (1978) The Livermore Regional Air Quality Model: II Verification and Sample Application in the San Francisco Bay Area. J. Appl. Meteorol., 17, 273-311.

Model Designation: Urban Airshed Model

Developed by: System Applications, Inc.
950 Northgate Drive
San Rafael, California 94903
(415) 472-4011

Model Description

The Urban Airshed Model is an Eulerian framework model having (optionally) several vertically stacked cells overlying each emission grid cell. It requires the calculation of self-consistent three-dimensional wind fields and accommodates assumptions regarding loss of pollutants to the ground. Computer requirements are very extensive.

Chemistry

The most recent chemical mechanism reported in connection with the Urban Airshed Model employs 75 reactions, using a so-called "carbon bond" approach in which each carbon atom is treated according to its bond type.

Emission Source Categories

All source categories are distinguished as either elevated or ground level. Elevated point sources are large VOC or NO_x emitters having effective stack heights above some established cutoff level. Ground level sources include minor (non-elevated) point sources, highway vehicles, and other area sources. VOC classes input to the model include single bonded carbon atoms, double carbon bonds, aromatic rings, carbonyl bonds, and ethylene-like double carbon bonds. Other pollutants required are NO, NO_2, CO, SO_2, and particulate.

Elevated Point Source Requirements

Input requirements include stack parameters for large point sources as well as emission data, to allow the program to allocate emissions to elevated grid cells.

References:

1. Ames, J. et al (1978), "The User's Manual for the SAI Airshed Model," draft report for Environmental Science Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, EM78-89, Systems Applications, Inc., San Rafael, California.
2. G. E. Anderson, S. R. Hayes, M. J. Hillyer, J. P. Killus, and P. V. Mundkur (1977) Air Quality in the Denver Metropolitan Region 1974-2000. Systems Applications, Inc., San Rafael, California, EPA No. 908/1-77-002.
3. Jerskey, T.N., and J.H. Seinfeld (1976), "Continued Research in Mesoscale Air Pollution Simulation Modeling--Volume IV: Examination of the Feasibility of Modeling Photochemical Aerosol Dynamics," EPA-600/4-76-016d, Systems Applications, Incorporated, San Rafael, California.
4. Jerskey, T.N., et al. (1976), "Continued Research in Mesoscale Air Pollution Simulation Modeling--Vol. VII: Mathematical Modeling of Urban Aerosol Dynamics," EF76-144, Systems Applications, Incorporated, San Rafael, California.
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Model Designation: Caltech Model

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Model Description

The Caltech Model utilizes an Eulerian framework, having (optionally) several vertically stacked cells overlying each emissions grid cell. It requires the calculation of self-consistent three-dimensional wind fields and accommodates assumptions regarding the loss of pollutants to the ground. Computer requirements are very extensive.

Chemistry

The most recent chemical mechanism is said to involve 58 reactions and six main classes of VOC's designated as paraffins, aromatics, ethylene, other olefins, formaldehyde, and other aldehydes.

Emission Source Categories

Tabulated hourly emissions are entered for as many categories as needed. For major point sources, stack height and heat flux parameters must be provided.

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APPENDIX B

ACRONYMS AND ABBREVIATIONS

GLOSSARY OF TERMS

ACRONYMS AND ABBREVIATIONS

ABAG - Association of Bay Area Governments
ADT - Average Daily Traffic
AP-42 - "Compilation of Air Pollutant Emission Factors," Publication No. AP-42, U.S. Enviromental Protection Agency, Research Triangle Park, NC
APRAC2 - A link-based traffic network emissions model, more data-intensive than HWYEMIS1
AQCR - Air Quality Control Region
CBD - Central Business District
CTG - Control Techniques Guideline
DOT - The U.S. Department of Transportation
EIS/P&R - Emission Inventory System/Permits and Regulation Subsystem
EKMA - Empirical Kinetic Modeling Approach
EPA - The U.S. Environmental Protection Agency
GVW - Gross Vehicle Weight
HC - Hydrocarbons
HDD - Heavy Duty Diesel Vehicle
HDG - Heavy Duty Vehicle, Gasoline Fueled
HWYEMIS1 - A link-based traffic network emissions model
I/M - Inspection and Maintenance
LDT - Light Duty Trucks
LDT1 - Light duty, gasoline-powered trucks, having gross vehicle weight 6,000 pounds or less
LD[illegible] - Light duty, gasoline-powered trucks, having gross vehicle weight more than 6,000 pounds but not more than 8,500 pounds
LDV - Light Duty Vehicle
LOADVN - A computer program in the PLANPAC/BACKPAC urban transportation program planning battery of computer program that is used in the trip assignment process
MC - Motorcycle
MOBILE1 - A computer model, approved by EPA, for estimating motor vehicle emission factors; preferred over the earlier "modal model"
MPO - Metropolitan Planning Organization
NEDS - National Emissions Data System
NMHC - Nonmethane Hydrocarbons
NO_x - Oxides of Nitrogen
OBERS - Office of Business Economics, Research Service
O-D - Origin-Destination
O_3 - Ozone

ACRONYMS AND ABBREVIATIONS

PLANPAC/BACKPAC - An urban transportation planning battery of computer programs available through the Federal Highway Administration. This battery lacks some of the multimodal planning capabilities included in the more recent Urban Transportation Planning Systems.

RACT - Reasonably Available Control Technology

RVOC - Reactive Volatile Organic Compounds

SAPOLLUT - A link-based traffic network emissions model, now largely superseded by HWYEMIS1 and APRAC2

SMSA - Standard Metropolitan Statistical Area

SO_x - Oxides of Sulfur

SPEED - A computer program in the PLANPAC/BACKPAC urban transportation planning battery of computer programs used to determine vehicle speed based on the volume/capacity relationship and other land and other land use and facility characteristics.

TRPTAB - A program in the PLANPAC/BACKPAC system, used to generate the number of zone-to-zone traffic interchanges

TSP - Total Suspended Particulates

UROAD - A computer program in urban transportation planning systems used in the trip assignment process.

USGS - United States Geological Survey

UTM - Universal Transverse Mercator

UTPS - Urban Transportation Planning System

VMT - Vehicle Miles Traveled

VOC - Volatile Organic Compound

GLOSSARY OF TERMS

Activity level - Any variable parameter associated with the operation of a source of emissions which is proportional to the quantity of pollutant emitted.

Aldehyde - A carbon compound containing the aldehyde functional grouping (-CHO).

Algorithm - Instruction for computing; usually in reference to computer programs.

Allocation factor - Used for distributing emissions spatially or temporally.

Ambient measurement - Measurement of concentrations of pollutants in the ambient atmosphere.

Area source - The aggregate of all emission sources in a particular source category, except those treated in an emission inventory as point sources (q.v.). All mobile source categories are area sources.

Area type - A general land use descriptor. A frequent classification system is CBD, fringe, suburban, and rural.

Aromatic - A carbon compound containing aromatic nuclei, sometimes called "benzene rings."

Average daily traffic - The average number of vehicles passing a specified point during a 24-hour period.

Background concentration - The concentration of a pollutant in the ambient air of a region as measured by monitors unaffected by sources within the region (i.e., by "upwind" monitors).

Baseline projection - Estimate of emissions expected in future years, based on a conservative scenario of growth and emission controls. Baseline emission controls for a given projection year include only those controls that have been legally mandated at the time of preparing the projection.

Baseline projection inventory - An inventory of emissions expected in a future year, based on best available projections of population and employment and assuming that only currently mandated emission controls will be in force (i.e., no new control strategies).

Breathing loss - Loss of vapors from storage tanks due to diurnal warming and cooling.

Capacity - The maximum number of vehicles reasonably expected to pass over a section of highway in a specified time under specified conditions. Also known as "level of service."

Carbon bond mechanism - A chemical mechanism intended for use in photochemical simulation models. It differs from other current mechanisms in the manner of lumping VOC species.

Catalyst - A material which, without being consumed, promotes a chemical reaction. Afterburners containing catalysts are used for control of VOC emissions from gasoline-fueled vehicles.

Centroid - An assumed point in a traffic zone that represents the origin or destination of all trips to or from that zone.

Centroid connector - A synthetic roadway link representing travel on local or collector streets, connecting a zone centroid to the actual highway network.

Chemical reaction rate - The rate at which a reactant is consumed or a product generated by a chemical reaction, usually given as rate of change of concentration.

Cold start - For catalyst-equipped vehicles, startup of an engine which has not been operated during the previous hour. For other vehicles, startup of an engine which has not been operated during the previous 4 hours.

Composition - The proportion of various species or classes of species present in a mixture of chemical substances (e.g., the composition of VOC present in a polluted atmosphere can be expressed in terms of the fractions of paraffins, olefins, aromatics, and other chemical groups).

Control strategy projection inventory - An inventory of emissions, for a future year, which differs from the baseline inventory in that it takes into account the expected impact of a proposed control strategy.

Deterioration rate - The estimated linear rate of change in average emissions from a motor vehicle exhaust system over 10,000 miles or 1 year of driving.

Diurnal pattern - The variation of emission rate or activity source with time of day; usually expressed as the fraction or percentage of the daily total occurring in each hour of the day.

Double bond - A type of carbon-atom linkage which exists in olefins, but not in paraffins.

Effective stack height - The height of the horizontal plume centerline above the base of the stack, equal to physical stack height plus height of plume rise.

Emission factor - For point sources, the factor relating uncontrolled emissions to activity levels. For area sources, the factor relating net emissions to activity levels.

Emission factor model - A computer model for estimating emission factors, usually in reference to motor vehicle emissions.

Emission inventory - A compilation of information relating to sources of pollutant emissions, including location, source strength, control devices, stack parameters, and often additional details.

Emissions, cold start - Motor vehicle emissions occurring within about 505 seconds after a cold start (q.v.).

Emissions, diurnal - (See Emissions, vehicle related).

Emissions, hot soak - Motor vehicle emissions originating in evaporation of fuel from the carburetor after engine shutdown.

Emissions, hot transient - Motor vehicle emissions occurring within about 505 seconds after a hot start. (q.v.)

Emissions, travel related - Motor vehicle emissions which occur while a vehicle is in a hot, stable operating mode. Also referred to as "exhaust emissions" and "hot stable mode emissions".

Emissions, trip-end related - Motor vehicle emissions related to engine startup and shutdown. They include "cold startup" and "hot transient" emissions, occurring on startup, and "hot soak" emissions, which occur on shutdown.

Emissions, vehicle related - Motor vehicle emissions caused by diurnal changes in ambient temperature, independent of vehicle operation. Also called "diurnal" emissions.

Empirical Kinetic Modeling Approach - A source-receptor relationship developed by EPA for estimating the overall reduction of volatile organic compound emissions needed in an urban area, based on existing oxidant levels and VOC/NOx ratios.

Evaporative losses - VOC emissions caused by the vaporization of materials, such as gasoline and solvents.

Facility type - Roadway classification (e.g., freeway, major arterial, etc.).

Forecast - Prediction of future conditions or occurrences. A forecast differs from a projection in that the latter may be contingent on various assumptions (for example, in control-strategy scenarios).

Gasoline marketing - The operations and systems associated with the transportation of gasoline from refineries to bulk terminals, bulk storage, service stations, and vehicle tanks.

Grid cell - One square of a grid system (q.v.).

Grid model - An air quality simulation model which provides estimates of pollutant concentrations for a gridded network of receptors, using assumptions regarding the exchange of air between hypothetical box-like cells in the atmosphere above an emission grid system. Mathematically, this is known as an "Eulerian" model.

Grid spacing - In a grid system used in photochemical modeling, the distance between successive grid points, which is equal to the length of each side of a grid square.

Grid square - Same as "grid cell." See grid system.

Grid system - A network formed by two mutually perpendicular sets of parallel lines dividing an area into square cells called grid cells or grid squares.

Hot start - Startup of a catalyst-equipped vehicle which has been operated within the previous hour.

Hybrid model - A traffic network emissions model in which estimates of the three major components of automotive emissions are prepared by separate methodologies.

Hydrocarbon - (1) In chemistry, any compound containing only carbon and hydrogen. Common types of hydrocarbons are paraffins (alkanes), olefins (alkenes), and aromatics. (2) In air pollution usage, equivalent to "volatile organic compound" (VOC) and recently being supplanted by that term, since some VOC's are not, chemically, hydrocarbons.

Impedance - In traffic assignment, a factor representing resistance to travel.

Land use planning model - A system of computer programs constituting tools for forecasting geographical distribution of various uses of land in a planning area.

Land use projection - Estimate of land use in a future year (often given in terms of land use maps representing the projected conditions).

Land use trip generation rate - A rate establishing the ratio between number of trips and a land use or socio-economic indicator.

Link - In traffic assignment, a section of a highway network defined by a node at each end.

Lumping - In chemical mechanisms, the stratagem of representing certain components by surrogate or hypothetical species, in order to reduce the assumed number of elementary reactions to a manageable number.

Methane - The simplest hydrocarbon species; often excluded from VOC measurements or inventories because it is essentially unreactive in atmospheric photochemical reactions.

Mobile source - Any self-propelled source of air pollutants, such as motor vehicles, vessels, locomotives and aircraft.

Modeler's tape - Magnetic tape carrying data formatted for direct input to a computer model, such as an air quality simulation model.

Mole - An amount of a chemical species whose weight is the molecular weight in weight units; e.g., for NO, having molecular weight = 30, a gram mole is 30 grams, a pound mole is 30 pounds, etc.

Mole percent - The number of moles of a given component in 100 moles of a mixture. In gaseous mixtures, equivalent to volume percent.

National Emission Data System - An automatic data processing system developed by EPA for storage and retrieval of source and emission data.

Nitric oxide (or nitrogen monoxide) - One of the two oxides of nitrogen which are collectively referred to as NOx (q.v.). The amount of NO in NOx is often reported in terms of the equivalent weight of NO_2, in which case its true weight is only 30/46 of the reported weight.

Nitrogen dioxide - One of the two oxides of nitrogen which are collectively referred to as NOx (q.v.). The total weight of NOx is often reported "as NO_2", which is not the true weight of the mixture but the weight which would be attained if all the NO were converted to NO_2.

Node - A numbered point of a transportation model network, designating the end-point of a link and usually representing a street intersection.

Nonmethane - Excluding methane.

Nonmethane hydrocarbon - All hydrocarbons, or all VOC, except methane.

Office of Business Economics, Research Service - (Used in reference to projections prepared jointly by the U.S. Department of Commerce, Bureau of Economic Affairs, Office of Business Economics and the U.S. Department of Agriculture, Economic Research Service, for the U.S. Water Resources Council, April 1974.)

Olefin - A carbon compound characterized by a type of unsaturation known as a "double bond".

Operating pattern - (See diurnal pattern).

Origin-destination survey - A detail study of existing travel demand and characteristics made by home and driver interviews.

Oxides of nitrogen - In air pollution usage, this comprises nitric oxide (NO) and nitrogen dioxide (NO_2); usually expressed in terms of the equivalent amount of NO_2.

Ozone - A toxic substance formed in the photochemical reactions involving volatile organic compounds and oxides of nitrogen; the principal chemical component of the photochemical oxidant formed in photochemical air pollution.

Ozone precursors - Volatile organic compounds and oxides of nitrogen, as air pollutant emissions and as air contaminants. Under the influence of ultraviolet light from the sun, these precursors react to form photochemical oxidants, including ozone.

Paraffin - A saturated, nonaromatic hydrocarbon compound.

Photochemistry - The chemistry of reactions which are promoted by light.

Plume rise - Height of the horizontal centerline of a plume above the stack top or other point of origin of the plume.

Point source - Generally, any stationary emission source for which individual records are maintained for emission inventory purposes; distinguished from "area source," often by a criterion involving emission rate, such as 100 tons per year.

Profile - (1) Chemical composition of a VOC mixture, in terms of individual compounds (VOC species) or classes of compounds (VOC classes); (2) Time-dependence of the concentration of a compound or class of compounds, depicted graphically.

Reactive class - See "Species class."

Reactivity - A measure of the rate at which an organic compound will react, in the presence of sunlight and oxides of nitrogen, to promote the formation of photochemical oxidants.

Reactivity class - See "Species class."

Receptor - A hypothetical sensor or monitoring instrument, usually a unit of a hypothetical network overlaid on the map of an area being modeled. In Eulerian "grid" models, one receptor is usually assumed at the center of each grid square.

Rollback model - A method of estimating degree of control of emissions needed to achieve a specified air quality in a region, based on the assumption that pollutant concentrations will be proportional to emissions in the region.

Seasonal adjustment - Used with reference to annual average rates of pollutant emissions, this is the factor needed to calculate daily or hourly average rates for one season (in the case of ozone, summer rates are most commonly required).

Secondary traffic - In some transportation models, traffic on streets not included as links in the model.

Simulation model (air quality) - A model which estimates pollutant concentrations by a series of calculations meant to simulate physical and chemical processes in the atmosphere, rather than by direct application of mathematical or statistical formulas.

Single bond - The type of carbon-atom linkage characteristic of paraffins.

Solvent - Any liquid organic compound used for dissolving other substances.

Source/receptor relationship - A model or relationship that predicts ambient pollutant concentrations based on precursor emission strengths. Photochemical simulation models are among source/receptor relationships for ozone.

Spatial resolution - (1) The process of determining or estimating what emissions may be associated with individual grid cells or other subcounty areas, given totals for a larger area such as a county. (2) The degree to which a source can be pinpointed geographically in an emission inventory.

Species - With regard to VOC, a species is any particular volatile organic compound (e.g., methane; 2-hexene; 1,1,1-trichloroethane). With regard to NO_x, a species is either nitric oxide (NO) or nitrogen dioxide (NO_2).

Species class - Any subset of VOC species, combined in accordance with rules specified by the input instructions for a photochemical simulation model. Also called"reactive class" or "reactivity class."

Speed, input - In traffic assignment, the speed included on the link description.

Speed, output - In traffic assignment, the speed on a link after capacity restraint.

Split factor - The factor by which total VOC emissions in a given category must be multiplied to give VOC emissions belonging to a certain class of compounds, as required for use in a photochemical simulation model. Also, the factor by which NOx emissions must be multiplied to determine NO or NO_2 emissions.

Stack parameters - Parameters characteristic of a stack and its associated plume, as required for input to some models; typically, stack height, inner diameter, volume flow rate, temperature of gas (needed to calculate plume rise).

Stationary source - Any non-mobile source of air pollutants.

Surrogate indicator - (1) For spatial resolution, a quantity whose areal distribution is known or has been estimated and may be assumed to be similar to that of the emissions from some source category whose areal distribution is unknown. (2) For growth, a quantity for which official growth projections are available and whose growth may be assumed to be similar to that of activity in some source category for which projections are needed.

Temporal resolution - (1) The process of determining or estimating what emissions may be associated with various seasons of the year, days of the week or hours of the day, given annual totals or averages. (2) A measure of the smallest time interval with which emissions can be associated in an inventory.

Traffic assignment - In a transportation model, the process of determining the route of travel, allocating zone-to-zone trips by these routes, and accumulating traffic volumes by link.

Traffic volume - A measure of the total number of vehicle miles traveled in unit time on a given link of a traffic network.

Trajectory - The path (over the map of a region) described by a hypothetical parcel of air moved by winds. The air parcel is identified as being at a given location at a given time, and the trajectory connects its hypothetical locations at earlier and later times of day.

Trajectory model - An air quality simulation model which provides estimates of pollutant concentrations at selected points and times on the trajectories of hypothetical air parcels which move over an emission grid system. Mathematically, this is known as a "Lagrangian" model.

Transportation planning model - A system of computer programs constituting tools for forecasting needs for and performance of future transportation systems in an urban area.

Trip distribution - In traffic assignment, the process by which movement of trips between zones is estimated.

Trip end - Either a trip origin or trip destination; or, if the Gravity Model has been used in the transportation modeling, a trip production or trip attraction.

Trip generation model - A model representing the relationship between trip makers and trip making. The product is trip ends per traffic zone.

Trip table - A table showing trips between zones. The trips may be separated by mode, by purpose, by time period, and by vehicle type.

Universal Transverse Mercator - A coordinate system for identifying locations of sources (or other features) on a map, based on distances in kilometers from established reference points on the earth's surface.

Urban Transportation Planning System - An urban transportation planning battery of computer programs distributed jointly by the Urban Mass Transit Administration and the Federal Highway Administration. It is the most recent battery of programs from the Department of Transportation.

Validation - (1) In principle, a demonstration of the validity of a model, such as an air quality simulation model. (2) In air pollution usage, more often an evaluation of model performance by means of a comparison between model estimates and observed air quality data. In this sense, often called "verification."

Vehicle miles traveled - An estimated total of number of miles traveled by all vehicles, or by all vehicles of a given category, in a specified region for a specified period of time; often used as a surrogate indicator for spatial resolution of motor vehicle emissions.

Vehicle mix - Composition of vehicular traffic in terms of the fraction of vehicle miles traveled by various classes of vehicles.

Vertical resolution - In regard to meteorological parameters and concentrations of pollutants in ambient air, the provision (in a model) of means for taking into account various values at different heights above ground.

Volatile organic compounds - Any hydrocarbon or other carbon compound which can be present in the gas phase in the atmosphere, with the exception of carbon monoxide, carbon dioxide, carbonic acid, carbonates, and metallic carbides.

Volume percent - The number of volumes of a given component in 100 volumes of a mixture. In gaseous mixtures, equivalent to mole percent.

Weight percent - The number of weight or mass units of a given component in 100 units of a mixture.

Zone - A subdivision of a study area, constituting the smallest geographic area for which data are aggregated and basic analyses made.